CHAPTER SIX

POTENTIAL DANGER TO HUMAN HEALTH AND THE ENVIRONMENT

LIST OF EXHIBITS

LIST OF EXHIBITS (cont.)

CHAPTER SIX

POTENTIAL DANGER TO HUMAN HEALTH AND THE ENVIRONMENT

6.0 INTRODUCTION

Section 8002(o)(3) of RCRA requires that EPA's study of CKD waste analyze potential danger to human health and the environment from disposal. In response to this requirement, EPA assessed the risks of potential releases of CKD contaminants to the environment, both during the routine management of the dust at cement plants and when the dust is beneficially used at other locations. This assessment relies heavily on the information developed on the amounts and characteristics of CKD generated (discussed in Chapter 3), CKD management practices (discussed in Chapter 4), and alternative CKD management practices and uses (summarized in Chapter 8). In addition, the risk assessment is intended to complement the damage case study presented in Chapter 5. The damage cases provide actual instances of environmental contamination, sometimes attributable to management practices and facility settings not considered in the risk assessment. The risk assessment covers the potential for certain more subtle or long-term risks that might not be evidenced in the damage case files.

This chapter summarizes the methods and results of EPA's risk assessment of CKD disposal and use. Additional details on various aspects of the study are provided in *Technical Background Document, Human Health and Environmental Risk Assessment in Support of the Report to Congress on CKD Waste* (referred to as the "Risk Assessment Technical Background Document" in the rest of this chapter). Before presenting the specific elements of the study, this section provides background on the purpose and scope of the risk assessment, as well as an overview of the study approach. This introduction also summarizes the major results and conclusions that are developed in greater detail in the remainder of the chapter.

Purpose and Scope

One of the primary objectives of the risk assessment was to investigate, as realistically as possible, the baseline risks of CKD management practices at actual sites. This was accomplished by focusing on a sample of case-study cement plants and off-site beneficial use scenarios that appeared to reasonably represent the universe of sites where CKD is disposed and used. For each sample site, EPA evaluated the potential for CKD contaminants to be released into the environment, migrate to possible human and ecological receptors, and result in exposures and adverse effects. This evaluation included a combination of qualitative analyses designed to document and describe major factors contributing to (or limiting) risks, and quantitative modeling designed to estimate the magnitude of risks. The study focused on the potential for releases and exposures through all media and pathways (ground water, surface water, air, and the food chain), and examined risks both to maximally exposed individuals and total populations around each case-study site.

Recognizing that potentially higher risk conditions may exist at other sites not included in the case-study sample, EPA designed the study to evaluate potential adverse effects under a variety of hypothetical scenarios. These scenarios were constructed by modifying the conditions evaluated at the case-study sites to reflect a reasonable worst-case set of waste characteristics, environmental settings, or CKD management practices.

Overall, the study examines the range of conditions that exist across the industry, while also focusing on those scenarios that have the greatest potential for adverse effects. The case studies are believed to fairly represent the range of risks that exist at "typical" sites. At the same time, to characterize the upper end of the risk distribution, priority was given to identifying and evaluating those management scenarios that pose the greatest threat.

Overview of Approach

The risk assessment approach consisted of three primary steps, as shown in Exhibit 6-1. First, the Agency conducted an "initial risk screening" of the chemical concentrations in CKD. Using EPA's sampling data for 20 cement plants, as well as data provided by industry, this screening compared chemical concentrations to a set of criteria. Concentrations that fell below these screening criteria were judged to pose a low or negligible risk that did not need further study. Conversely, concentrations above the criteria indicated that more detailed study was needed to determine the risks associated with certain CKD constituents, exposure pathways, and facility-specific waste streams under more realistic management conditions. This initial risk screening is summarized in Section 6.1.

Second, those constituents, exposure pathways, and CKD waste streams that could not be ruled out based on the initial risk screening were evaluated at a sample of actual cement plants. For each of the 15 plants visited during the 1992 sampling study, EPA collected site-specific data on a number of management practices and environmental factors that influence the potential for damage through releases to ground water, surface water, and air when the dust is managed on site at cement plants. Based on an analysis of these factors, the facilities were grouped into risk potential categories (negligible, low, moderate, and high) for each pathway. The Agency then performed quantitative modeling to estimate the human health and environmental risks at five of these 15 plants in order to estimate both central tendency and high end risks. In addition, the sensitivity of these modeled risk results to selected key parameters was examined in order to identify potentially higher risk management scenarios and environmental settings not captured by the 15 sample sites. Section 6.2 summarizes this evaluation of risks when CKD is managed on site at cement plants.

Third, those constituents, exposure pathways, and CKD waste streams that the initial risk screening could not exclude from further study were evaluated in the context of off-site beneficial uses. The Agency reviewed data on the nature, extent, and location of off-site CKD uses to identify five case studies for further risk analysis. These cases represented five major categories of off-site use: 1) hazardous waste stabilization and disposal, 2) sewage sludge stabilization and use, 3) building materials addition, 4) road construction, and 5) agricultural liming. EPA collected data on major risk factors for each case study to determine the potential for adverse effects and to prioritize the beneficial use categories for quantitative modeling. Hypothetical scenarios designed to represent the two categories that appeared to pose the highest risk were then developed and modeled for the purpose of risk estimation. This analysis of off-site beneficial uses is presented in Section 6.3.

Exhibit 6-1

Overview of Risk Assessment Methodology

Major Results and Conclusions

Major results and conclusions from the evaluation of potential danger to human health and the environment from the management of CKD are presented below.

- The pH of CKD leachate measured in laboratory tests typically ranged from 11 to 13. High pH levels in ground water and surface water may result in a variety of adverse effects, including the mobilization of certain metals and other constituents that could pose toxicological problems, human tissue burns (at pH levels above 12.5 or more), corrosion in pipes, and objectionable taste in drinking water. In addition, high pH levels could cause a wide variety of adverse ecological effects.

- Seventeen radionuclides were found in detectable concentrations in CKD, including members of the naturally occurring uranium-238 and thorium-232 decay chains and anthropogenic radionuclides that have been dispersed throughout the environment along with fallout from nuclear weapons tests. The concentrations of these radionuclides in CKD, however, are not elevated compared to the range of natural background levels, and modeling results for those nuclides with the highest potential for adverse health effects showed negligible risk.

- Based on a detailed qualitative review of site-specific risk factors at 15 representative cement plants, on-site CKD handling and disposal does not appear to have a high potential for adverse human health and environmental risks. However, selected risk factors, observed or reported at these or other cement plants, required more detailed qualitative evaluations.

- Quantitative risk modeling of case-study plants yielded central tendency risk estimates for cancer and noncancer health effects that were below levels of concern. Of the seven potential exposure pathways examined in this baseline analysis, including direct contact and indirect foodchain pathways, estimated increased individual cancer risks never exceeded a level of $1x10^{-6}$ (most pathway risks never exceeded $1x10^{-8}$). The noncancer hazard estimates were always less than one order of magnitude of the noncancer effects threshold.

- Modeling estimates of high end risks from on-site management indicated a greater potential for human health effects. High end facility cancer risks due to recreational exposures to surface water reached an upper bound value of $2x10^{-5}$; the ingestion of vegetables grown in agricultural fields contaminated by CKD reached an upper bound cancer risk of $3x10^{-6}$, and consumption of recreationally-caught fish reached an upper bound risk of $4x10^{-5}$. The other high end direct and indirect exposure pathway estimates were all less than $1x10^{-6}$.

- Although the central tendency results for the baseline risk modeling analysis showed no exceedances of ambient water quality criteria or other aquatic ecological benchmarks, the high end results indicated a potential for aquatic ecological damages. The high end ecological risks reflect contributions of CKD from overland run-off, atmospheric deposition, and ground-water discharge all entering the receiving water body. While most of the high end results indicated that aquatic ecological benchmarks would be exceeded by small amounts for most constituents, two constituents (cadmium and chromium) exceeded benchmarks by more than two orders of magnitude and two others (arsenic and lead) exceeded by a factor of ten or more.

- The sensitivity analysis of hypothetical but plausible (based on conditions infrequently observed) higher risk scenarios indicated a potential for more significant human health threats in a number of scenarios. These analyses indicated that the proximity to potential exposure points (such as agricultural fields and surface water bodies), high end concentrations of individual toxic constituents (such as dioxins, arsenic, or heavy metals), or the possible presence of extreme exposure situations (such as subsistence food consumption), would be major factors that could increase the potential for damages from CKD plants.

- Dioxins/furans did not contribute substantially to cancer risks for either the central tendency or high end plants in the baseline case studies. Sensitivity analysis, based on high end measured dioxin concentrations, also suggested negligible or low risks in the direct exposure pathways. However, for indirect foodchain pathways, high dioxin concentrations applied to base case plant settings increased central tendency cancer risks to levels as high as $1x10^{-4}$ and high end plant risks to as high as $1x10^{-3}$.

- Sensitivity analyses indicated that, other factors being equal, CKD units located adjacent to crop fields and pastures or surface water bodies (both settings having been observed in field site visits) would increase general health and/or aquatic resource damages by an order of magnitude or more over the base-case estimates.

- Although subsistence level food consumption exposure patterns were not observed in the field or otherwise reported to the Agency, sensitivity analyses incorporating these extreme indirect foodchain exposure situations yielded the highest estimated risks in the EPA studies. Although these subsistence consumption risks did not exceed levels of concern for the central tendency base case plants, when combined with any other high end risk factor, cancer risks typically exceeded $1x10^{-4}$ for subsistence fish consumption and $1x10^{-5}$ for subsistence farming.

- Off-site beneficial byproduct use of CKD as a stabilizing agent for hazardous waste, sewage sludge stabilizer, road sub-base, asphalt additive, and additive for building materials (e.g., concrete and masonry block) does not appear to pose significant risks to human health or the environment. Although there is some potential for releases of CKD contaminants and subsequent exposures when the dust is used in the construction of unpaved roads and parking lots, modeling of a parking lot scenario indicates that this risk should be small (predicted cancer risks of $1x10^{-7}$ or lower and noncancer risks of at least two orders of magnitude below effects thresholds for all potential exposure pathways).

- Utilization of CKD as an agricultural liming agent appears to pose more of a risk than other byproduct beneficial uses. The Agency's analysis indicated that cancer risks and noncancer effects could exceed relevant levels of concern in the foodchain pathway in several scenarios for those CKD sources with very high concentrations of arsenic and dioxins. While best estimate risks indicated a maximum exposure to a subsistence farmer of about $7x10^{-6}$ due to arsenic, the upper bound risks in this exposure scenario reached a maximum of $2x10^{-4}$ as a result of dioxin exposures.

6.1 INITIAL RISK SCREENING

EPA started its risk assessment by comparing the concentrations of chemicals measured in CKD to a set of benchmarks, or "risk-screening criteria." These criteria were developed using accepted toxicity values and chemical release, transport, and exposure assumptions that represent reasonable mismanagement scenarios when CKD is managed on site at cement plants. EPA first compared chemical concentrations to the screening criteria to identify CKD constituents that need further study to determine if there is a potential to pose a human health or environmental risk when the dust is managed on site. The Agency then evaluated other chemical and physical properties (i.e., mobility and persistence in the environment, and normal background concentrations) that may tend to mitigate, intensify, or otherwise qualify the risks associated with those CKD constituents found at levels above the screening criteria.

The purpose of this initial risk screening was threefold:

- To identify individual CKD constituents that may have the potential to pose risks, and, if so, how pervasively across cement plants;

- To identify exposure pathways that are most likely to convey risks (ground water, surface water, air, and direct contact); and

- To identify CKD waste and product streams on a facility-specific basis that may have the potential to pose risks under reasonable mismanagement scenarios.

Those CKD constituents, exposure pathways, and CKD streams believed to pose a low or negligible risk based on the results of the risk screening could be excluded from further analysis. Conversely, those constituents, pathways, and CKD streams that could not be ruled out based on this initial screening would warrant a closer, site-specific assessment. The Agency then proceeded to analyze these constituents, pathways, and cement plants in more detail in subsequent steps of the risk assessment.

The remainder of this section summarizes the methods and results of this initial risk screening. More detail is provided in the Risk Assessment Technical Background Document. Section 6.1.1 provides a brief overview of the risk screening approach and methods. Section 6.1.2 presents the risk-screening results for different exposure pathways, and discusses their implications for subsequent steps in the risk assessment.

6.1.1 Approach and Methods

This section describes the CKD composition data, risk-screening criteria, and other constituent-specific factors used in the initial risk screening.

CKD Composition Data

For the purpose of the initial risk screen, EPA examined the concentrations of 25 dioxins and furans, 14 metals, 17 radionuclides, fluoride, and pH.[1] The screening focused primarily on concentrations measured during the Agency's 1992 and 1993 sampling study, introduced in Chapter 1. EPA believes that it is appropriate to focus this risk screen on its own sampling data (as opposed to data from the PCA Survey, PCA Reports, and Bureau of Mines) for three main reasons:

- EPA's data set is the only source of data on dioxins, furans, and radionuclides (the other sources do not provide any data on these constituents);

- The Agency data can be related in all instances to specific waste management practices and environmental settings for subsequent case-study purposes; and

- As discussed in Section 3.2.2 of this report, a statistical analysis indicates that the vast majority of calculated mean concentrations for metals in the EPA sampling data are not significantly different than the means from the other data sources.

Nevertheless, the Agency recognizes that the other data sources report higher concentrations of some metals than observed in the EPA sampling, and that limiting this initial risk screening to only the EPA sampling data might ignore some metal concentrations that would yield higher risk

[1] EPA also measured the concentrations of chloride, total organic carbon, total cyanide, sulfate, and sulfide in CKD totals analyses during the 1992 sampling. The Agency did not examine these chemicals in the risk screening, however, as there are no accepted toxicity values on which to base screening criteria.

conclusions. Therefore, the risk screen also considered the full range of metal concentrations reported in the other data sources.

EPA's data set of constituent concentrations consists of a total of 45 CKD samples from 20 different cement plants, including ten facilities that burn hazardous waste as fuel and ten facilities that do not burn hazardous waste. Not all samples were analyzed for every constituent, however. Metals data (both totals and leach extract) are available for 15 facilities, and dioxins data are available for 11 facilities (although only six facilities have leachate data). The number of facilities for which radionuclide data are available ranges from seven to 20, depending on the particular radionuclide and test type. For this analysis, EPA did not differentiate between the "as generated" and "as managed" dust samples, but rather combined the sampling results (there were 24 "as generated" samples and 21 "as managed" samples). Similarly, the results from TCLP and SPLP extract analyses, discussed in Chapter 3, were not differentiated for the initial risk screen.

Leachate extract analyses were conducted for dioxins, furans, and radionuclides at the six cement plants examined in the 1993 sampling, but not at the 15 plants examined in 1992. The Agency filled this data gap by estimating leachate concentrations of these constituents for the 1992 sampling results. In particular, EPA determined the median ratio of total concentrations to leachate extract concentrations observed for each dioxin, furan, and radionuclide examined in the 1993 sampling, and then multiplied these ratios by the corresponding total concentrations observed in 1992. These estimated leachate concentrations were then pooled with the measured concentrations from 1993 for comparison to the risk-screening criteria.

Risk-Screening Criteria

Because this evaluation was intended to identify constituents, pathways, and CKD streams that warrant further analysis and rule out those that present negligible risk, EPA designed the screening criteria to be reasonably "conservative" to avoid false negative conclusions. That is, the criteria are based on release, transport, and exposure assumptions that are more likely to indicate risk than actual CKD management practices at cement plants.

Separate criteria were developed for four release and exposure pathways: ground water, surface water, air, and on-site direct contact. For the ground-water pathway, the Agency used two criteria to evaluate the potential for adverse health effects through drinking water exposures: one based on the drinking water primary Maximum Contaminant Levels (MCLs) and the other based on health-based levels (HBLs). Four criteria were used for surface water: two for evaluating the potential for human exposure through drinking water (based on the same MCLs and HBLs used for the ground-water criteria), one for evaluating the potential for aquatic ecological effects (based on the Ambient Water Quality Criteria), and one for evaluating the potential for human exposure through fish ingestion. One criterion was developed for the air pathway and the on-site direct contact pathway. The basis for each of the risk-screening criteria is summarized in Exhibit 6-2. The Risk Assessment Technical Background Document provides more detail on the derivation of these criteria, as well as the numerical values used for the different criteria.

An individual lifetime cancer risk of $1x10^{-5}$ was used as the basis for the screening criteria for carcinogens, indicating that the chance of an individual contracting cancer over a 70-year lifetime,[2] as a result of the exposure being assessed, is approximately 1 in 100,000. This

[2] EPA assumed a 70-year exposure duration in developing the risk-screening criteria as one means of ensuring that the criteria are conservative (i.e., to help avoid false negative conclusions in this step of the analysis). In the risk modeling step of the analysis, EPA assumed an exposure duration of 9 years, which is the 50th percentile (median) duration of occupancy at one residence (*Exposure Factors Handbook*, U.S. EPA Office of Health and Environmental Assessment, EPA/600/8-89/043, July 1989). The Agency used 9 years in the risk modeling to develop a risk estimate that is more realistic than the conservative risk potential conclusions from the initial risk

risk level is consistent with EPA policy of selecting risk management targets between $1x10^{-4}$ and $1x10^{-6}$ (55 FR 8716; March 9, 1990). An individual cancer risk of $1x10^{-5}$ is appropriate for developing screening criteria in this context because the total population exposed to CKD is relatively small, and because using a lower target risk in conjunction with the conservative exposure assumptions underlying the screening criteria would unnecessarily compound the conservatism of the criteria. For example, assuming a 70-year exposure duration introduces substantial conservatism compared to the 9-year average exposure duration assumed in most current generic risk assessments (assuming a 9-year exposure would raise the screening criteria for carcinogens by a factor of almost eight). Using a higher target risk would be inappropriate because the screening analysis was designed to be reasonably conservative and to minimize false negatives.

To develop the ground-water and surface water pathway criteria, EPA used a dilution and attenuation factor (DAF) to account for the decrease in concentration that occurs as contaminants are released from a waste management unit, mix in the flow of ground water or surface water, and migrate to a location where a person, plant, or animal might be exposed. A DAF of 10 was used for the ground-water pathway and a DAF of 100 was used for the surface water pathway (i.e., adverse effect levels were multiplied by 10 for the ground-water criteria and by 100 for the surface water criteria). These are the same DAFs that EPA used in conducting a similar risk-screening analysis in the Report to Congress on Special Wastes from Mineral Processing.[3] The Agency believes that these factors account for a minimal amount of dilution and attenuation in ground water and surface water under reasonable CKD mismanagement scenarios.

screen.

[3] *Report to Congress on Special Wastes from Mineral Processing*, Volume II, Methods and Analyses, U.S. EPA Office of Solid Waste, July 1990.

Exhibit 6-2

Basis for Risk-Screening Criteria[a]

Screening Criterion		Major Underlying Assumptions and Parameters
Ground-water Pathway	10x Primary MCL	The Primary Maximum Contaminant Levels (MCLs) established for drinking water supplies are designed to be protective of human health. Ten times the primary MCL represents the constituent concentrations in CKD leachate that could result in an exceedance of the primary MCL (and the risk of associated adverse human health effects) if the leachate is released and migrates in ground water to a downgradient drinking water well with less than a 10-fold dilution. In the case of pH, the Agency used one standard unit above the upper bound of the secondary MCL (equivalent to a factor of 10) because there is no primary MCL. The secondary MCL for pH is intended to limit corrosivity and taste effects, not necessarily adverse health effects.
	10x Health-Based Level	The Agency developed health-based levels (HBLs) using chemical-specific toxicological values along with equations for calculating preliminary remediation goals for ground water at Superfund sites. These levels assume that an adult directly ingests contaminated ground water and inhales volatile contaminants from whole-house water use (such as from the shower or faucet). The HBLs are based on an individual lifetime cancer risk of $1x10^{-5}$ for carcinogens and noncancer effect thresholds for noncarcinogens. The Agency multiplied these HBLs by 10 to develop criteria that represent concentrations in CKD leachate that may pose health risks if leachate is released and migrates in ground water to a nearby drinking water well with less than a 10-fold dilution.
Surface Water Pathway	100x Primary MCL	These are the same MCLs used for the ground-water criteria, simply multiplied by 100 rather than 10 to account for greater dilution expected in surface water.
	100x Health-Based Level	These are the same HBLs used in deriving the ground-water criteria, but multiplied by 100 instead of 10.
	100x AWQC	When available, the Agency used chronic ambient water quality criteria (AWQC) for freshwater organisms. When AWQC were not available, the Agency derived "AWQC-like" values by extrapolating lowest observed adverse effect levels for chronic exposures of freshwater organisms. These criteria are designed to be protective of aquatic organisms (not humans), accounting for the potential for constituents to bioconcentrate and cause adverse effects through food chain exposures.
	Human Fish Ingestion Health Factor	The Agency developed human health screening criteria for contaminated fish ingestion using chemical-specific toxicological values and bioconcentration factors, along with equations for calculating exposure from the ingestion of contaminated fish at Superfund sites. The levels are based on an individual lifetime cancer risk of $1x10^{-5}$ for carcinogens and noncancer effect thresholds for noncarcinogens. The Agency multiplied these levels by 100 to develop criteria that represent concentrations in CKD leachate that may pose human health risks if constituents are released, migrate to a surface water with only a 100-fold dilution, and bioconcentrate in fish that are consumed by humans.
Air Release-Off-site Exposure Pathway		These criteria represent concentrations that, if CKD is suspended in air and transported to a downwind receptor location, could lead to an individual lifetime cancer risk of $1x10^{-5}$ or an exceedance of a noncancer effect threshold. The underlying assumptions are that particulates from a CKD pile are blown into the air by the wind, dispersed to a hypothetical "backyard gardener's" property located 230 meters (750 feet) away, and deposited onto soil and vegetables at that point. The receptor is then assumed to be exposed to CKD contaminants via four routes: (1) inhalation of particulates; (2) incidental ingestion of soil contaminated by airborne deposition of particulates (i.e., inadvertent ingestion of soils as a result of normal mouthing of objects or hands); (3) ingestion of leafy vegetables contaminated by deposited particulates; and (4) for radionuclides, exposure to direct radiation from the contaminated ground surface without any shielding.
On-site Direct Contact Pathway		These criteria are based on a highly conservative, hypothetical scenario in which an individual is assumed to live directly on uncovered CKD, and over a lifetime, incidentally ingests the dust, inhales particulates suspended into the air, inhales constituents that have volatilized from the dust, and is exposed to direct radiation with no shielding. No dilution is taken into account; the exposed individual is assumed to live directly on CKD, not CKD mixed with soil or any other material. The criteria are based on an individual lifetime cancer risk of $1x10^{-5}$ for carcinogens and noncancer effect thresholds for noncarcinogens. The Agency calculated these levels using equations and parameters developed for calculating preliminary remediation goals for soil at Superfund sites.

[a] See the Risk Assessment Technical Background Document for the numerical values used for each criterion and more detail on their derivation.

To develop appropriate screening concentrations for dioxins and furans, EPA followed the methodology presented in *Interim Procedures for Estimating Risks Associated with Exposures to Mixtures of Chlorinated Dibenzo-p-dioxins and -Dibenzofurans (CDDs and CDFs), 1989 Update*. According to this methodology, concentrations of 2,3,7,8-substituted CDDs and CDFs (i.e., CDDs and CDFs with a chlorine substituted on the 2, 3, 7, and 8 carbon atoms) are converted to equivalent concentrations of 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD), the most potent carcinogen that has been evaluated by EPA. Equivalent concentrations of 2,3,7,8-TCDD for each 2,3,7,8-substituted congener[4] are calculated by multiplying the concentration of each 2,3,7,8-substituted congener by its respective toxicity equivalent factor (TEF). CDDs and CDFs that do not have chlorine substitutions at the 2, 3, 7, and 8 carbons are assigned a TEF of zero. After each congener is multiplied by its TEF, the concentrations for all the congeners are summed to determine the 2,3,7,8-TCDD equivalent for the mixture.

Other Constituent-Specific Factors

For those constituents found to exceed one of the risk-screening criteria, the Agency evaluated three other constituent-specific factors that may affect the potential for human health and environmental risks. These other factors were used to qualify the results of the criteria comparisons, not as a basis for excluding constituents of potential concern from the analysis. The values used in evaluating each of these factors are outlined in the Risk Assessment Technical Background Document.

First, the Agency evaluated each constituent's mobility in ground water[5] by examining its soil-water partition coefficient (K_d), which reflects the tendency of a chemical to attach to soil.[6] EPA evaluated this factor because, even though a constituent may exist in CKD leachate in relatively high concentrations, it may pose little or no risk to off-site receptors if it migrates very slowly in ground water.

Second, each constituent's persistence in the environment was evaluated. A constituent that degrades rapidly may not pose a substantial risk, even if it exists in relatively high concentrations. Many constituents present in CKD are elements that do not degrade in the environment. However, EPA evaluated the half-life of dioxins in ground water as reported in the U.S. Department of Energy's (DOE's) MEPAS database. The persistence of dioxins in air or surface water was not evaluated, because the travel time in these media to a possible exposure point is nearly instantaneous. For radionuclides, EPA used radioactive half-lives documented in the *Radiological Health Handbook* (1970) published by the U.S. Public Health Service.

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[4] The term "congener" refers to any one member of the same chemical family. There are 75 congeners of chlorinated dibenzo-p-dioxins; seven of these have chlorine substituted at the 2, 3, 7, and 8 carbons. Likewise, there are 135 congeners of chlorinated dibenzofurans; ten of these have chlorine substituted at the 2, 3, 7, and 8 carbons.

[5] EPA assumed that all constituents would be mobile in surface water or air if released to these media.

[6] This partition coefficient, or K_d, represents the equilibrium ratio of a chemical adhering to soil that is present in ground water. The Agency reviewed each constituent's K_d as developed by EPA's Office of Research and Development (ORD) (documented in EPA's Corrective Action chemical database). If a value was not developed by ORD, K_d values were selected from the Department of Energy's *Chemical Data Bases for the Multimedia Environmental Pollutant Assessment System* (MEPAS). Both of these sources provide K_d values for different pH categories, and EPA selected values from the highest pH category to best represent conditions that are most likely to exist in CKD leachate.

Third, EPA evaluated the normal background concentrations of radionuclides in the environment. Most of the radionuclides detected in CKD are naturally occurring (such as members of the uranium-238 and thorium-232 decay chains), while others are anthropogenic but have become ubiquitous in the environment (such as cesium-137 and plutonium-238/239, which exist essentially everywhere due to fallout from nuclear weapons tests). The Agency reviewed background concentration data available in the literature and provided by DOE. If a radionuclide was found to exist in CKD in concentrations within the normal range found in the environment, it may not pose a risk that warrants special attention.

6.1.2 Risk-Screening Results

Although substantial variability was found in the concentrations of individual contaminants at the 20 facilities sampled, all 20 facilities had one or more constituents that exceeded the risk-screening criteria for every pathway. The constituents that exceeded screening criteria at each facility are presented in Exhibit 6-3.[7] (For additional detail, including the magnitude of exceedances at each facility, see the Risk Assessment Technical Background Document.) As shown, every facility had at least four constituents that exceeded the ground-water pathway criteria, at least one constituent that exceeded the surface water pathway criteria, and at least five constituents that exceeded the very conservative on-site direct contact criteria. In addition, every facility tested for metals had CKD that exceeded the air release off-site exposure criteria for at least one constituent.

Those facilities that burn hazardous waste as fuel are identified in Exhibit 6-3 with an asterisk. For the most part, the facilities that burn hazardous waste as fuel had the same constituents exceeding screening criteria by the same order of magnitude as the facilities that do not burn hazardous waste. However, dioxin, lead, chromium, pH, and Tl-208 levels at hazardous waste burners tended to exceed certain criteria by a slightly wider margin than at other facilities. Conversely, thallium, Bi-214, Pb-214, and Ra-226 concentrations tended to exceed the criteria by a slightly wider margin at facilities that do not burn hazardous waste.

In terms of the results for individual constituents, the initial risk screening suggests the following:

- Ground Water. The constituents needing further study for ground water are antimony, arsenic, thallium, and pH. Dioxins (2,3,7,8-TCDD equivalents), lead, beryllium, and cadmium also exceeded risk screening criteria, but these constituents are relatively immobile under the high pH conditions expected for CKD leachate (they would be expected to migrate readily only at sites where fractures or solution cavities exist in the subsurface). In addition, K-40, Ra-228, and U-238 exceeded the screening criteria, but these radionuclides appear to be present in CKD in concentrations that are within the range of background levels found in normal rock and soil.

[7] The absence of a chemical for a given facility in Exhibit 6-3 may be the result of a lack of data for that facility, rather than the result of low chemical concentrations that fall below the screening criteria. Specifically, dioxins were not analyzed at Facilities B, C, G, I, J, L, N, Q, and S. Metals were not analyzed at Facilities K, M, P, R, and T. Radionuclide data also are not available for every facility.

Exhibit 6-3

CKD Constituents That Exceeded Risk-Screening Criteria at EPA Sample Facilities[a]

Facility	Ground-water Pathway[b]	Surface Water Pathway: 100x MCL or 100x HBL[b]	Surface Water Pathway: 100x AWQC[b]	Surface Water Pathway: Fish Ingestion[b]	Air Release - Off-site Exposure Pathway[a]	On-site Direct Contact Pathway
Facility A*	Sb, As, Pb, K-40, pH	pH, K-40	Pb, pH	Tl	As, Cr	As, Pb, Bi-214, K-40, Pb-214, Ra-226, Ra-228, Tl-208
Facility B	As, Pb, Tl, K-40, pH	K-40, pH	pH	Tl	As, Cr	As, Be, Bi-214, Pb-214, K-40, Ra-226, Ra-228, Tl-208
Facility C*	As, Pb, K-40, pH	Pb, K-40, pH	Pb, pH		As, Cr	Pb-214, K-40, Ra-226, Ra-228, Tl-208
Facility D	Sb, As, Tl, K-40, U-238, 2,3,7,8-TCDD equiv., pH	Tl, U-238, TCDD equiv., pH	pH	Tl, 2,3,7,8-TCDD equiv.	As, Cr	As, Tl, Bi-214, Pb-214, K-40, Ra-226, Ra-228, Tl-208, 2,3,7,8-TCDD equiv., TCDD+TCDF
Facility E	Sb, As, Tl, K-40, pH	K-40, pH	pH	Tl	As, Cr	As, Pb-214, K-40, Ra-226, Ra-228, Tl-208
Facility F*	Sb, As, Pb, K-40, U-238, 2,3,7,8-TCDD equiv., pH	Pb, K-40, pH	Pb, pH	Tl, 2,3,7,8-TCDD equiv.	As, Cr	As, Pb, Pb-214, K-40, Ra-226, Tl-208
Facility G	Sb, As, Pb, Tl, K-40, pH	Pb, Tl, K-40, pH	Pb, pH	Tl	As, Cr	As, Bi-214, Cs-137, Pb-214, K-40, Ra-226, Ra-228, Tl-208
Facility H*	As, Pb, K-40, U-238, 2,3,7,8-TCDD, equiv., pH	Pb, K-40, U-238, pH, 2,3,7,8-TCDD equiv.	Pb, pH, 2,3,7,8,-TCDD equiv.	Tl, 2,3,7,8-TCDD equiv.	As, Cr, 2,3,7,8-TCDD equiv.	As, Pb, Pb-214, K-40, Ra-226, Ra-228, Tl-208, 2,3,7,8-TCDD equiv., TCDD+TCDF
Facility I*	Sb, As, Pb, Tl, Ra-228, K-40, pH	K-40, pH	Pb, pH	Tl	As, Cr	As, Bi-214, Pb-214, K-40, Ra-226, Ra-228, Tl-208
Facility J	Sb, As, Pb, Tl, Ra-228, K-40, U-238, pH	K-40, U-238, pH	pH	Tl	As, Be, Cd, Cr	As, Be, Bi-214, K-40, Pb-214, Ra-226, Ra-228, Tl-208
Facility K	K-40, U-238, 2,3,7,8-TCDD equiv.	K-40, U-238		2,3,7,8-TCDD equiv.		Bi-214, K-40, Pb-214, Ra-226, Ra-228, Tl-208
Facility L	Sb, As, Pb, Tl, K-40, pH	Tl, pH	pH	Tl	As, Cr, Tl	Tl, Bi-214, K-40, Pb-214, Ra-226, Ra-228, Tl-208
Facility M	K-40, U-238, 2,3,7,8-TCDD equiv.	U-238		2,3,7,8-TCDD equiv.		Bi-214, K-40, Pb-214, Ra-226, Ra-228, Tl-208
Facility N*	Sb, As, Pb, K-40, pH	Pb, K-40, pH	Pb, pH	Tl	As, Cr	As, Be, Pb, Bi-214, Pb-214, K-40, Ra-226, Ra-228, Tl-208

Exhibit 6-3 (continued)

CKD Constituents That Exceeded Risk-Screening Criteria at EPA Sample Facilities[a]

Facility	Ground-water Pathway[b]	Surface Water Pathway			Air Release - Off-site Exposure Pathway[a]	On-site Direct Contact Pathway
		100x MCL or 100x HBL[b]	100x AWQC[b]	Fish Ingestion[b]		
Facility O*	Sb, As, Pb, Tl, Ra-228, K-40, U-238, 2,3,7,8-TCDD equiv., pH	K-40, U-238, pH	Pb, pH	Tl, 2,3,7,8-TCDD equiv.	As, Be, Cr	As, Be, Pb, Bi-214, K-40, Pb-212, Pb-214, Ra-226, Ra-228, Tl-208
Facility P*	Ra-228, K-40, U-238, 2,3,7,8-TCDD equiv., pH	U-238, pH	pH	2,3,7,8-TCDD equiv.	Th-228	Bi-214, K-40, Pb-214, Ra-226, Ra-228, Tl-208
Facility Q	As, Tl, K-40, pH	Tl	Tl	Tl	As, Cr, Tl	As, Tl, Bi-214, Pb-214, K-40, Ra-226, Ra-228, Tl-208
Facility R*	K-40, U-238, 2,3,7,8-TCDD equiv., pH	K-40, U-238, pH		2,3,7,8-TCDD equiv.		Bi-214, K-40, Pb-214, Pb-212, Ra-226, Ra-228, Tl-208
Facility S*	Sb, As, Pb, Tl, K-40, pH	pH, K-40	pH	Tl	As, Cr	As, Bi-214, Pb-214, K-40, Ra-226, Ra-228, Tl-208
Facility T	Ra-228, K-40, U-238, 2,3,7,8-TCDD equiv., pH	K-40, U-238, pH	pH	2,3,7,8-TCDD equiv.		Bi-214, K-40, Pb-214, Ra-226, Ra-228, Tl-208

* Burns hazardous waste as fuel.

[a] Dioxins were not analyzed at Facilities B, C, G, I, J, L, N, Q, and S. Metals were not analyzed at Facilities K, M, P, R, and T. Radionuclide data also are not available for every facility.

[b] Metals data reported by industry (not developed by EPA) indicate that, in addition to the above exceedances, beryllium and cadmium occasionally exceed ground-water screening criteria, arsenic occasionally exceeds the HBL-based surface water criterion, and mercury occasionally exceeds the AWQC-based and fish ingestion criteria. Because the identity of the facilities exceeding the criteria for these constituents is not known, they could not be displayed in this exhibit.

- Surface Water. Dioxins and furans (2,3,7,8-TCDD equivalents), lead, thallium, arsenic, K-40, U-238, and pH need further study to determine their potential drinking water threats. Dioxin, lead, thallium, mercury, and pH levels exceeded the AWQC-based criteria and require further study to determine their potential for aquatic ecological risk. Considering the potential for these constituents to bioconcentrate in fish tissue, dioxins, thallium, and mercury could pose an added threat of human exposures through the fish ingestion pathway. Of these constituents, dioxins, lead, thallium, and mercury are relatively immobile in ground water (if fractures or solution cavities that facilitate flow do not exist) and thus would tend to migrate to surface water primarily by stormwater run-off or atmospheric deposition, rather than via ground-water discharge. In addition, the surface water risks associated with K-40 and U-238 do not appear to be greater than the risks associated with natural background radioactivity.

- Air. The constituents needing further study to determine airborne releases and exposures include dioxins (2,3,7,8-TCDD equivalents), arsenic, beryllium, cadmium, thallium, and chromium (conservatively assuming all of the chromium in CKD is present in its more toxic hexavalent form). Th-228 also could pose a risk via the air pathway, but no more than the risk associated with natural background concentrations of this radionuclide.

- On-site Direct Contact. Dioxins, arsenic, beryllium, lead, thallium, and eight radionuclides may be present at some facilities in concentrations that may be harmful under the highly conservative scenario in which an individual lives directly on uncovered CKD. Although the radionuclides may pose a risk under this exposure scenario, this radiation threat should not be any greater than that associated with natural background radioactivity.

Based on these screening results, EPA concluded that more detailed study was needed to determine the risks of several CKD constituents, exposure pathways, and facility-specific waste streams. The Agency proceeded to evaluate these risks more closely by examining existing conditions at a sample of actual cement plants and off-site locations where CKD is beneficially used.

6.2 EVALUATION OF RISKS WHEN CKD IS MANAGED ON SITE

In the second step of the risk assessment, EPA conducted a closer examination of the cement plants and CKD constituents that were found to have the potential for risks in the initial risk-screening. The results of the preceding analysis of constituent concentrations in CKD were combined with a site-specific evaluation of CKD management practices and environmental settings at a sample of actual cement plants.

This more detailed evaluation of risks was conducted in two phases. First, EPA evaluated the "risk potential" at initial case-study facilities by analyzing a number of site-specific factors relating to the potential for on-site CKD management to pose risks via ground-water, surface water, and air pathways. The purpose of this evaluation was to document and describe the major factors contributing to or limiting risk at each case-study facility, and to prioritize the facilities for further analysis through quantitative modeling. This evaluation of risk potential is presented in Section 6.2.1.

Second, the Agency performed quantitative modeling to estimate the magnitude of risks associated with on-site CKD management at cement plants. In particular, site-specific modeling was performed to estimate the risks at case-study cement plants that could pose higher risks based on the preceding evaluation of risk potential. The Agency also modeled potentially higher risk scenarios not captured by the sample of cement plants considered in the evaluation of risk potential. This risk modeling of on-site CKD management is presented in Section 6.2.2.

6.2.1 Risk Potential Ranking of Initial Case Studies

This section summarizes the methods and results of the risk potential ranking conducted by EPA to determine factors that strongly influence the risks of on-site CKD management and to prioritize cement plants for risk modeling. The Risk Assessment Technical Background Document provides more detail on this evaluation.

Approach and Methods

EPA focused this ranking on a subset of the constituent concentration data and 20 sample facilities analyzed in the initial risk screening. Only some of the constituents and facilities were examined to develop an initial sample of case-study facilities that could be evaluated on a "level playing field." In particular:

- Dioxin concentrations were not considered because only 11 of the 20 sample facilities were analyzed for dioxins. Considering dioxins, therefore, would have resulted in artificially high risk potential rankings for some facilities that are based more on data availability than on true differences that exist across sites.

- The five cement plants sampled by EPA in 1993 were not considered. These facilities were excluded from the risk potential ranking because their CKD was not tested for metals, which could result in a bias in the ranking.

It is important to clarify that EPA excluded dioxins and the five facilities sampled in 1993 only from this risk potential ranking and not from the rest of the risk assessment. As discussed in Section 6.2.2, the Agency modeled the risks of dioxins under several actual and hypothetical management scenarios, as well as potential higher-risk conditions found at some of the five facilities sampled in 1993, but not observed in the sample of 15 facilities sampled in 1992.

EPA believes that it is reasonable to focus on the 15 cement plants sampled in 1992 as initial case-study facilities because they appear to provide a representative sample of other cement plants. Specifically, the sample is large and diverse, representing approximately 10 percent of the universe of existing U.S. cement plants as well as a diversity of fuel types, process types, and geographic locations (e.g., eight of the facilities burn hazardous waste as fuel and seven do not). Moreover, the sample of 15 cement plants compares favorably with the complete set of 83 plants for which data are available, as shown in Exhibit 6-4. Specifically, the two sets of facilities are quite similar in terms of a number of factors that influence risk, including CKD management unit types, the size of CKD management units, the proximity to "sensitive" environmental features (karst terrain, geological faults, 100-year floodplains, and endangered species habitats), the number of residents presently within one mile, and the distance to the nearest existing residence. The 15 sample facilities, however, generate relatively large volumes of net CKD compared to the broader set of 83 plants, and do not represent the management of CKD underwater (which is practiced at three of the 83 facilities). Finally, a statistical analysis indicates that the concentrations of metals in CKD at these 15 facilities are similar to the concentrations observed at other cement plants. As discussed in Section 3.2.2, most of the calculated mean concentrations for metals at the 15 sample facilities are not significantly different than the means from other data sources that cover a larger sample of facilities (including PCA Report 2, which provides data on the concentration of metals in CKD from 79 cement plants).

Exhibit 6-4

Comparison of 15 Sample Facilities to Other Facilities

Parameter	Range of Values for 15 Sample Facilities	Range of Values for All 83 Facilities for Which Data are Available[a]
Total net CKD generated	25% ≥ 63,500 MT (70,000 tons) 50% ≥ 40,500 MT (45,000 tons) 75% ≥ 16,500 MT (18,200 tons)	25% ≥ 53,500 MT (59,000 tons) 50% ≥ 21,800 MT (24,000 tons) 75% ≥ 1,100 MT (1,200 tons)
CKD management unit type	60% landfill CKD in an on-site quarry 27% manage CKD in an above-grade pile 13% (2 facilities) have no active CKD unit	43% landfill CKD in an on-site quarry 40% manage CKD in an above-grade pile 11% landfill CKD in other units (mines, slopes) 1% (1 facility) manage CKD in a pond 4% use other management units
CKD managed underwater?	100% no	97% no 3% (3 facilities) yes
Basal area of CKD management unit(s)	25% ≥ 63,500 m^2 (683,000 ft^2) 75% ≥ 6,700 m^2 (72,000 ft^2)	25% ≥ 58,600 m^2 (630,000 ft^2) 75% ≥ 3,700 m^2 (39,800 ft^2)
Facility in karst area?	80% no 20% yes	85% no 15% yes
Facility in fault area?	67% no 33% yes	86% no 14% yes
Facility in 100-year floodplain?	47% no 53% yes	60% no 40% yes
Facility in endangered species habitat?	100% no	98% no 2% yes
Number of residents presently within one mile of property boundary	25% ≥ 1,020 people 75% ≥ 25 people	25% ≥ 2,020 people 75% ≥ 33 people
Distance from property boundary to nearest existing off-site residence	25% ≥ 850 m (2,800 ft) 75% ≥ 15 m (50 ft)	25% ≥ 790 m (2,600 ft) 75% ≥ 30 m (100 ft)

[a] A total of 79 cement plants, including 11 of 15 sample facilities, returned completed PCA mail survey questionnaires. Comparable data for the other four sample facilities were developed during the sampling visits.

For the sample of 15 cement plants, the Agency analyzed site-specific information on a number of factors that determine the degree to which CKD constituents are likely to be released into the environment and transported to locations where humans or ecological receptors could be exposed. The particular factors considered are listed in Exhibit 6-5. As shown, EPA conducted separate analyses of factors that relate to the potential for CKD management to pose risks via the ground-water, surface water, and air pathways (including risks from the ingestion of food contaminated through these different pathways). For each pathway, four sets of factors were systematically considered at every site:

- Factors related to the intrinsic hazard of CKD. These factors included the frequency and magnitude with which chemical concentrations and pH levels exceeded the risk-screening criteria discussed in Section 6.1. Again, dioxins were not considered in this step to avoid biasing the ranking toward the subset of facilities whose CKD was analyzed for dioxins. In addition, EPA did not consider immobile constituents in the ground-water pathway ranking, or radionuclides for any pathway because they were all measured in CKD at levels that fall within the range of typical background levels.[8]

- Factors related to ground-water, surface water, and air contamination potential. These factors included CKD management practices (size of pile, presence of liners and run-off controls, dust suppression practices, etc.) and environmental features (e.g., depth to ground water, distance to surface water, and wind speeds) that have a bearing on the potential for contaminants to migrate from waste management units and contaminate environmental media.

- Factors related to transport potential. These factors included the presence of natural and man-made barriers to contaminant migration in environmental media, such as slurry walls or surface water bodies that might impede the migration of ground-water contaminants, and karst terrain or fractures that may facilitate contaminant migration in ground water. The distance to closest potential receptors also was considered as a transport potential factor, giving the risk potential ranking an element of a maximum exposed individual (MEI) risk assessment.

- Factors related to exposure potential. These factors included the present human uses of nearby ground water, surface water, and air, as well as the size of potentially exposed populations. By considering the size of potentially exposed populations, the ranking also included elements of a population risk assessment. Depending on the size of the population, this factor had the effect of moderating or intensifying the risk potential ranking based on MEI distances alone.

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[8] EPA believes that leaving immobile ground-water contaminants and radionuclides out of this ranking provides a more realistic evaluation of risk potential. However, once a facility was selected for risk modeling based on this ranking, all constituents that exceeded one of the risk-screening criteria were modeled.

Exhibit 6-5

Site Specific Factors Used to Evaluate Risk Potential of On-Site CKD Management

The Agency assembled site-specific values for each of these factors using, when available, information collected during the site visits. When data were not available from the site visits, a variety of sources were used to fill in data gaps, including the PCA mail survey, local offices of State governments and the U.S. Geological Survey (USGS), USGS topographic maps, the Graphical Exposure Modeling System (GEMS), and environmental data collected by EPA for nearby facilities as part of other risk assessment projects.

For each pathway (ground water, surface water, and air), the various factors were combined to develop rankings (negligible, low, moderate, and high) regarding intrinsic hazard, contamination potential, transport potential, and exposure potential at each site. The Agency then combined these four rankings to develop an overall ranking of the ground-water, surface water, and air risk potential at each plant. In developing this overall ranking for the different media, the lowest ranking was selected from among the scores assigned to intrinsic hazard, contamination potential, transport potential, and exposure potential. For example, if the ground-water pathway at a facility was assigned a low intrinsic hazard, a high contamination potential, a moderate transport potential, and a moderate exposure potential, the facility was assigned an overall low ground-water risk potential. In this way, the Agency evaluated the individual risk factors to determine if there were any factors that would limit the potential for significant risk at a given site. If a risk-limiting factor was identified (e.g., intrinsic hazard was low, as in the above example), the overall risk for that pathway could not be high. Chapter 7 of the Risk Assessment Technical Background Document describes this methodology in more detail, presents the individual factors and criteria used to develop risk potential rankings, and documents the results for each of the 15 case-study facilities.

In performing this ranking, EPA considered only the current conditions that exist at each cement plant, such as the current CKD pile sizes and containment features, the current land and water use practices in surrounding areas, and the current population distributions in off-site areas. Insufficient data were available to support a meaningful analysis and prediction of possible future conditions. However, significant changes in the current conditions at these 15 plants could result in some facilities being assigned higher or lower risk potential rankings.

Results of Risk Potential Ranking

The case-study site rankings represent best professional judgments on the potential for current CKD management practices at the 15 sample plants to pose risks to human health and the environment, based on the analysis of factors outlined above. The results provide a means of evaluating the risk potential at each of the 15 sites relative to each other, not a definitive assessment of the absolute risk at each site (e.g., a site ranking cannot be translated into a numeric cancer or non-cancer risk estimate). Considering the rigor of the methodology, this ranking provides a credible basis for prioritizing the sites and selecting plants that warrant risk modeling. At the same time, the results indicate the general level of risk expected to exist at each site, based on the Agency's understanding of risk-influencing parameters and the results of previous risk analyses and modeling projects. This is especially the case for sites that are assigned a negligible risk potential, where one or more site factors allow the Agency to conclude, with some certainty, that risks for a given release and exposure pathway are indeed sufficiently low to be ignored. As previously discussed, available information indicates that the site conditions and distribution of risk potential rankings across the sample of 15 plants reasonably represents the larger universe of active cement plants, but may not reflect particularly high-risk conditions or factors that have been discovered at the damage case sites or observed during site visits.

<u>Risk Potential Ranking for the Ground-water Pathway</u>

Exhibit 6-6 summarizes the risk potential rankings for the ground-water pathway at the 15 sample cement plants. These rankings address only the potential for human health risks through drinking water ingestion, not the potential for health or ecological risks associated with the discharge of contaminated ground water to a surface water body (which are considered in the next section on surface water risk potential). As shown, the Agency developed separate hazard potential rankings for each plant based on the intrinsic hazard of chemical concentrations and pH levels in CKD leachate. The plants are ordered in the exhibit from highest to lowest ground-water risk potential based on the concentrations of chemicals in CKD leachate. The risk potential ranking of the plants considering pH levels is slightly different, as indicated by the number in parentheses in the far right column.

Based on the results in Exhibit 6-6, none of the 15 facilities are expected to pose an overall high ground-water risk. Although the Agency's methodology ranked certain factors in isolation as having a high risk potential, the scores for these individual factors were moderated when combined with the other factors that determined overall site risk. For example, even though the potential for ground-water contamination was ranked high at Facility G, the overall risk potential for the facility was ranked moderate considering the other factors (intrinsic hazard, transport potential, and exposure potential) that influence risks at the site.

The Agency ranked four facilities as having an overall moderate risk potential for the ground-water pathway, considering the chemical concentrations in CKD leachate. In order of descending risk potential, these are Facilities G, A, C, and J. These same facilities also were ranked among the top considering pH levels of the CKD leachate. Facilities A and C burn hazardous waste as fuel, while Facilities G and J do not use hazardous waste as an alternative fuel. The primary factors that contributed to these facilities being ranked relatively high included:

- At Facility G, the potential for ground-water contamination appears high because, among other factors, the water table is shallow (0.3 to 1 meter [1 to 3 feet] beneath the CKD pile), the underlying soils are a permeable sand, and net recharge is high (38 cm/year, or 15 in/year). However, the potential for ground-water contamination to migrate to off-site drinking water wells and result in significant exposures is only moderate because the nearest downgradient residence is approximately 1,600 meters (one mile) from the CKD pile. Furthermore, local water suppliers have stated that residences in the area derive their drinking water from community water systems (although ground water is used for domestic purposes in the area and the possibility of a private well at nearby residences cannot be ruled out). The size of the population that may be exposed to any ground-water contamination within a mile downgradient of the facility's CKD pile is about 20 people.

- At Facility A, the contamination potential is not as high as at Facility G because the material underlying the CKD pile is a less permeable limestone and siltstone and because the net recharge is smaller (15 cm/year). As at Facility G, ground water is used for domestic purposes in the area, but according to local water suppliers, residences around Facility A derive their drinking water from a nearby river. If any nearby residences do have private wells, the nearest downgradient residence that may be exposed to ground-water contamination is about 490 meters (1,600 feet) from the CKD pile and the total population within a mile downgradient is 450 people, larger than the potentially exposed population at Facility G.

Exhibit 6-6

Risk Potential Rankings for the Ground-water Pathway

Facility	Intrinsic Hazard Potential		Ground-water Contamination Potential	Transport Potential	Current Exposure Potential[a]	Overall Ground-water Risk Potential (Rank)	
	Chemical	pH				Chemical	pH
Facility G	Moderate	High	High	Moderate	Moderate	Moderate (1)	Moderate (2)
Facility A*	Moderate	Moderate	Moderate	Moderate	High	Moderate (2)	Moderate (3)
Facility C*	Moderate	Moderate	High	Moderate	Moderate	Moderate (3)	Moderate (5)
Facility J	Moderate	High	Moderate	Moderate	Moderate	Moderate (4)	Moderate (4)
Facility D	High	High	Low	High	High	Low (5)	Low (9)
Facility I*	Low	High	Moderate	Moderate	High	Low (6)	Moderate (1)
Facility F*	Low	Moderate	Moderate	Moderate	High	Low (7)	Moderate (6)
Facility B	Low	Moderate	Moderate	High	Moderate	Low (8)	Moderate (8)
Facility S*	Low	High	Moderate	Moderate	Moderate	Low (9)	Moderate (7)
Facility O*	Moderate	High	Moderate	Low	Negligible	Negligible (10)	Negligible (10)
Facility H*	Moderate	Moderate	Moderate	Low	Negligible	Negligible (11)	Negligible (11)
Facility N*	Moderate	Moderate	Moderate	Low	Negligible	Negligible (12)	Negligible (13)
Facility E	Low	Moderate	Moderate	Low	Negligible	Negligible (13)	Negligible (12)
Facility Q	Moderate	Moderate	Negligible	Negligible	Negligible	Negligible (14)	Negligible (15)
Facility L	Moderate	High	Negligible	Negligible	Negligible	Negligible (15)	Negligible (14)

* Burns hazardous waste as fuel.

[a] Future development of ground-water uses around these facilities could increase the exposure potential rankings and, depending on the risk rankings for the other site factors (intrinsic hazard, ground-water contamination potential, and transport potential), could result in higher overall ground-water risk potential rankings.

- At Facility C, there appears to be a high potential to contaminate ground water because the water exists just three meters below the CKD pile, the unsaturated zone is moderately permeable (a clayey sand), and net recharge is high (33 cm/year). Although ground water is used as a drinking water source in the area, the nearest downgradient residence that may be affected is farther away from the CKD pile than at Facilities G and A (1,100 meters). Additionally, the only residence that might be affected by any ground-water contamination is located on site, in between the CKD pile and a large river, which borders the site. All other residences in the direction of ground-water flow are on the other side of the river and are unlikely to be exposed to any ground-water contamination originating from Facility C.

- At Facility J, the ground-water contamination potential appears moderate because the water table is moderately deep (9 meters), the net recharge is moderate (20 cm/year), and the permeability of the shale underlying the site's CKD pile is low. Ground water is presently used in the area for domestic purposes, and the nearest downgradient residence that may have a private well is roughly 550 meters from the CKD pile. There are approximately 40 people within a mile downgradient that may be exposed to any ground-water contamination originating from the pile.

Five facilities were ranked as having an overall low ground-water risk potential. All of these facilities were ranked as low because one or more critical factors that determine overall site risk potential were scored low according to the Agency's ranking methodology. For example, the intrinsic hazard of the chemical concentrations in CKD leachate at Facilities I, F, B, and S is low, making the overall ground-water risk potential low at those sites regardless of the ground-water contamination, transport, and exposure potential. Similarly, even though the intrinsic hazard of the dust at Facility D is ranked high, the overall ground-water risk potential at the site appears low because of the low potential for ground-water contamination at the site (the water table is about 30 meters deep, net recharge is very low, and the underlying clay and shale is very impermeable).

Six facilities were ranked as having an overall negligible ground-water risk potential. Two of these facilities, Q and L, were assigned a negligible hazard because they presently recycle all of their CKD and do not have an on-site CKD management unit. The other facilities were assigned a negligible hazard because there is a negligible potential for exposure to any ground-water contamination that might originate from on-site CKD management. In particular:

- All ground water at Facility O discharges directly into the site's quarry (ground water is pumped at the site to dewater the quarry). Even after mining operations cease and ground-water contours are allowed to return to normal, any ground-water contamination originating from the plant's CKD pile would migrate just 150 meters to the northern property boundary where it would discharge directly into a surface water body without being withdrawn for human use.

- If ground water beneath the CKD pile at Facility H were to become contaminated, it would likely discharge directly into a river with a large dilution potential located 1,200 meters downgradient. All of the property between the pile and the river is owned by Facility H and presently uninhabited.

- There presently are no residences within a 1,600 meters downgradient from the CKD pile at Facility N. Also, the nearest downgradient property boundary where off-site exposures could occur is relatively far (1,400 meters) from the CKD pile.

- Any ground-water contamination originating from the CKD pile at Facility E is expected to discharge directly to a river with a large dilution potential 370 meters downgradient without being withdrawn for human use (all of the property between the pile and the river is owned by Facility E and presently uninhabited). Even if all the contamination did not discharge into the river, the closest downgradient residence that could be exposed to the contamination is approximately 2,300 meters away.

Risk Potential Ranking for the Surface Water Pathway

Exhibit 6-7 summarizes the risk potential rankings of the 15 case-study cement plants for the surface water pathway. These rankings address the potential for human health risk via drinking water, fish ingestion, and other surface water uses, as well as the potential for risk to aquatic organisms. As for the ground-water pathway, the Agency developed two separate rankings, one considering only the concentrations of chemicals (not pH levels) in CKD leachate and the other considering both the concentrations of chemicals and pH levels. Contamination potential scores were developed by considering three contaminant migration pathways: stormwater run-off to surface water, ground water to surface water migration, and air deposition to surface water. The highest score from among these three scores at a given facility was selected as that facility's surface water contamination potential. The overall surface water risk ranking at a site was determined by selecting the lowest score for any of the critical factors at that site (i.e., intrinsic hazard, contamination potential, transport potential, and current exposure potential). The plants are ordered in Exhibit 6-7 from highest to lowest overall risk potential considering the concentrations of chemicals in CKD leachate. The alternate ranking considering pH levels is indicated in the far right column of the exhibit.

Based on these results, none of the 15 facilities are expected to present a high risk to human health and aquatic organisms via the surface water pathway. As discussed for the ground-water pathway, the Agency's methodology ranked some facilities high for one or more aspects, but at each facility, at least one critical factor lowered the overall risk potential. For example, Facility F scored high for transport potential, but received an overall moderate risk ranking when the other factors were considered.

As shown in Exhibit 6-7, EPA ranked seven facilities as having a moderate surface water risk potential. Five of these seven facilities (O, F, A, I, and N) burn hazardous waste as fuel. The main factors that contributed to these rankings include:

- At Facility O, CKD could blow into the air and deposit in a water body with a large surface area just 150 meters to the north. Additionally, after current ground-water pumping to dewater the quarry ceases, any ground-water contamination originating from the on-site CKD pile would be expected to migrate 150 meters to the north and discharge into the same water body. Such contamination, including possible increases in pH levels in affected areas, has the potential to cause ecological damage, but would not be expected to pose a human drinking water threat because the water is not used for drinking. The potential for surface water contamination via stormwater run-off appears low, given surface drainage patterns and ditches that divert run-off from the CKD pile into the quarry, through a series of settling ponds, and eventually out to the surface water body through an NPDES-permitted outfall.

- At Facility J, there is a potential for stormwater run-off carrying contaminants from the on-site CKD pile to migrate approximately 2,100 meters through a drainage ditch and discharge into a reservoir. Given the pile's containment features and the site's hydrogeology and meteorology, there also is a potential for CKD contaminants to migrate via ground-water discharge and airborne deposition to this same reservoir, located 1,000 meters directly downgradient and downwind from the on-site pile. This reservoir has minimal flow, so any contamination reaching the water is unlikely to be transported downstream and diluted significantly. In addition, there is a high potential for human exposures through the fish ingestion pathway because the reservoir is actively fished.

Exhibit 6-7

Risk Potential Rankings for the Surface Water Pathway

Facility	Intrinsic Hazard Potential		Surface Water Contamination Potential by Different Migration Pathways			Transport Potential	Current Exposure Potential[a]	Overall Surface Water Risk Potential (Rank)	
	Chemical	pH	Storm Water	Ground Water	Air			Chemical	pH
Facility O*	Mod.	Mod.	Low	Mod.	Mod.	High	High	Mod. (1)	Mod. (1)
Facility J	Mod.	Mod.	Low	Low	Mod.	High	High	Mod. (2)	Mod. (2)
Facility F*	Mod.	Mod.	Low	Mod.	Low	High	Mod.	Mod. (3)	Mod. (5)
Facility D	Mod.	Mod.	Mod.	Low	Low	High	Mod.	Mod. (4)	Mod. (4)
Facility A*	Mod.	Mod.	Mod.	Neg.	Low	High	Mod.	Mod. (5)	Mod. (3)
Facility I*	Mod.	Mod.	Mod.	Mod.	Mod.	Mod.	Mod.	Mod. (6)	Mod. (6)
Facility N*	Mod.	Mod.	Low	Neg.	Mod.	Mod.	Mod.	Mod. (7)	Mod. (7)
Facility G	Mod.	Mod.	Neg.	Low	Low	High	Mod.	Low (8)	Low (8)
Facility S*	Mod.	Mod.	Low	Neg.	Neg.	High	Mod.	Low (10)	Low (10)
Facility B	Mod.	Mod.	Low	Low	Low	High	Mod.	Low (9)	Low (9)
Facility E	Mod.	Mod.	Low	Mod.	Mod.	Low	Mod.	Low (11)	Low (11)
Facility C*	Mod.	Mod.	Low	Low	Mod.	Low	High	Low (12)	Low (12)
Facility H*	Mod.	Mod.	Low	Low	Mod.	Neg.	Mod.	Neg. (13)	Neg. (13)
Facility Q	Mod.	Mod.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg. (14)	Neg. (15)
Facility L	Mod.	Mod.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg. (15)	Neg. (14)

* Burns hazardous waste as fuel.

[a] Future development of surface water uses around these facilities could increase the exposure potential rankings and, depending on the risk rankings for the other site factors (intrinsic hazard, surface water contamination potential, and transport potential), could result in higher overall surface water risk potential rankings.

- At Facility F, there is a potential for contaminants to migrate through ground water from the on-site CKD pile to a creek located 600 meters downgradient. There also is a potential for windblown dust from the pile to deposit in the same creek, given the limited controls on dusting and the on-site meteorological conditions. This creek has a low flow and dilution capacity, and currently is used in the vicinity of the cement plant for agricultural purposes, creating the potential for human exposures through the food chain. Lead and pH levels measured in extract analyses of this facility's CKD also exceed AWQCs, indicating a potential for aquatic ecological damage if the creek is contaminated.

- At Facility D, a moderate potential for surface water contamination through stormwater run-off exists because run-off is only partly controlled and the nearest surface water body that may receive run-off is 300 meters away. In addition, there is a potential for this same creek to be contaminated by airborne deposition of CKD, because windblown dusting from the pile is not prohibited entirely (e.g., although the pile is occasionally wetted, it is not covered or compacted over its entire surface). The potentially receiving water body has a very low flow (annual average of 0.06 m^3/sec, or 2 cfs), and thus has a very limited dilution capacity. The low flow makes it unlikely that the water body is used as a human drinking water supply. However, thallium and dioxin concentrations measured in leachate extracts of the facility's CKD indicate a potential for human health risks through the fish ingestion pathway. The high pH levels of CKD leachate at the facility also create the potential for aquatic ecological damage.

- At Facility A, there is a contamination potential via the stormwater run-off and air migration pathways because of the close proximity of the nearest water body (15 meters), a moderate potential for windblown dusting from the site's CKD pile, and limited stormwater run-off controls. The potentially receiving surface water has a low dilution capacity (annual average flow of 2 m^3/sec), and people could come in direct contact with the receiving water at the point of contamination (i.e., the water body is off site and access to it is unrestricted). Given the water's low flow, any surface water contamination is probably not a human drinking water threat, although it could pose a health threat via the fish ingestion pathway (thallium appears to the primary constituent of potential concern for this pathway). Also, elevated lead and pH levels measured in leachate extracts of the plant's CKD indicate a potential for adverse aquatic ecological effects.

- At Facility I, the nearest water body to the CKD pile is a river located only 90 meters away. There is a potential for contaminants to migrate into the river through ground-water discharges because there is a moderate potential for ground-water contamination at the site (given limited engineering controls and the site's hydrogeology), the river is located in a downgradient direction, and the river is likely to receive ground-water inputs. A potential also exists for contaminants to migrate to the river via stormwater run-off and windblown dusting, given site meteorology and limited controls on the pile (e.g., stormwater is not diverted in drainage ditches or subject to NPDES permitting prior to discharge). However, the water's relatively large flow (annual average of 132 m^3/sec) is expected to significantly dilute any contamination that enters the river.

- At Facility N, CKD containment features and site environmental conditions combine to create a moderate potential for contaminants to blow into the air and deposit in a river about 1,400 meters from the on-site CKD pile. There also is a low potential for contaminants to migrate to this same creek along with stormwater run-off, given the pile's run-off controls and distance from surface water. The potentially receiving river has a moderate flow (annual average of almost 100 m^3/sec), can be accessed by people in the area where CKD contaminants would enter the water, and is presently used for recreation, fishing, and irrigation. Elevated lead and pH levels measured in leachate extract analyses of the facility's CKD also suggest the potential for aquatic ecological damage.

The Agency ranked five facilities as having an overall low risk potential for the surface water pathway. All of these facilities were assigned a relatively low surface water risk because one or more critical factors (e.g., low contaminant concentrations, low transport potential) were found to pose a low risk according to the Agency's ranking methodology.

Three facilities were ranked as having an overall negligible potential for surface water risk. As discussed for the ground-water rankings, two of these facilities, Facilities Q and L, were assigned a negligible risk potential because they presently recycle 100 percent of their CKD. The other facility, Facility H, was assigned a negligible surface water risk potential because the nearest surface water is located 1,200 meters from the on-site CKD pile. This relatively long distance makes it unlikely that the river will receive large CKD loads via any migration pathway (ground water, stormwater run-off, or air). Even if CKD migrated to the river, it would be quickly diluted because of the river's high flow in the vicinity of Facility H (over 5,000 m^3/sec on average).

When fully implemented, the Agency's recently promulgated stormwater runoff control regulations (described in Section 7.2.1 of Chapter 7) could substantially mitigate or eliminate human health risks and aquatic ecological damages to surface waters attributable to stormwater runoff of CKD contaminants. These regulations would not, however, control delivery of CKD contaminants to surface waters via ground-water or air pathways.

Risk Potential Ranking for the Air Pathway

The air pathway is of concern for CKD because the dust is a fine particulate matter that is readily suspendable, transportable, and respirable in air. In general, particles that are ≤100 micrometers (µm) may be suspended in the wind and transported. Within this range, particles that are ≤30 µm can be transported for considerable distances downwind. However, only particles ≤10 µm are respirable by humans. The significance of particulate size for CKD is illustrated in Exhibit 6-8, which displays the particle size distribution for dust samples by kiln type. Virtually all of the dust generated at the 15 case-study sites may be suspended and transported in the wind (i.e., the vast majority of particles are ≤100 µm), and over two-thirds of all dust particles generated may be transported over long distances. Additionally, a significant percentage of the total dust generated (from 22 to 95 percent, depending on kiln type) is comprised of respirable particles that are ≤10 µm.

In an effort to keep the dust down, many facilities add water to CKD prior to disposal to form larger clumps or nodules. In addition, as CKD sits in a pile exposed to the elements, occasional wetting by rainfall results in the formation of a thin surface crust in inactive areas of the pile. However, based on field observations during the site sampling trips, neither the formation of nodules nor the natural surface crusting eliminates the potential for CKD to blow into the air. Nodulizing the dust prior to disposal provides incomplete and temporary control because the entire dust volume is not nodulized and because the dust eventually dries and returns to a fine particulate that is available for suspension and transport. Likewise, a surface crust may develop, but (1) the crust breaks when vehicles or people move on the pile, and (2) fresh dust is regularly added to the pile providing a continual, exposed reservoir of fine particles.

Exhibit 6-8

Particle Size Distribution of CKD by Kiln Type[a]

Kiln Type	Number of Kilns in Case Study[b]	Percentage of Particles ≤100 µm	Percentage of Particles ≤30 µm	Percentage of Particles ≤10 µm
Long, wet rotary	20	95	77	53
Long, dry rotary	2	100	99	95
Dry, with precalciner	6	98	66	22

[a] Data for particle size distribution from: Todres, H.A. et al. 1992. *CKD Management Permeability*, Research and Development Bulletin RD103T, Portland Cement Association, Skokie, IL.

[b] The number of kilns represents the total number of kilns at the 15 facilities sampled in 1992, such that if one facility had three kilns each of the kilns was counted.

Although these intrinsic properties of CKD make the dust conducive to airborne suspension and transport, other site-specific factors must be considered when evaluating the overall risk potential for the air pathway. For this risk potential ranking, EPA has focused primarily on the potential for CKD releases as the dust is transported across a site and disposed in piles. The Agency recognizes that an unknown quantity of CKD also may be released from fugitive emissions during loading and unloading of vehicles transporting CKD, during CKD removal from the dust collection systems (e.g., electrostatic precipitators), and from other points in the process (e.g., process leaks or stack emissions). However, insufficient information was available to evaluate these potential release sources in a meaningful way in this risk ranking.

Exhibit 6-9 summarizes the air risk potential rankings for the 15 case-study cement plants. The Agency developed overall risk potential rankings based on the intrinsic hazard of the dust (based on total concentrations measured in dust), the air contamination potential, transport potential, and current exposure potential. The plants are listed in the exhibit from highest to lowest risk potential.

None of the facilities were ranked as posing a high risk potential for the air pathway considering the many site-specific factors that influence risk. Several facilities were ranked high for at least one critical factor, but this was moderated when combined with other factors. For example, the exposure potential was ranked high at Facility B, but other factors such as the intrinsic hazard of the facility's dust, the moderate exposed surface area of the pile (51,200 m^2 or 550,000 ft^2), the high precipitation-evaporation index (indicating a relatively moist environment), and the distance to the nearest residence (460 meters) suggest that overall risk potential is moderate rather than high.

The Agency ranked 11 facilities, including seven hazardous waste burners and four facilities that do not burn hazardous waste, as posing a moderate risk potential for the air pathway. The similarity in scores across the range of facilities is related to the similarities in intrinsic hazard scores (all 15 plants scored moderate for intrinsic hazard) and similarity in

Exhibit 6-9

Risk Potential Rankings for the Air Pathway

Facility	Intrinsic Hazard Potential	Air Contamination Potential	Transport Potential	Current Exposure Potential[a]	Overall Air Risk Potential (Rank)[b]
Facility A*	Moderate	Moderate	High	High	Moderate (1)
Facility J	Moderate	Moderate	High	Moderate	Moderate (2)
Facility D	Moderate	Moderate	High	High	Moderate (3)
Facility B	Moderate	Moderate	Moderate	High	Moderate (4)
Facility G	Moderate	Moderate	Moderate	High	Moderate (5)
Facility F*	Moderate	Moderate	Moderate	Moderate	Moderate (6)
Facility O*	Moderate	Moderate	Moderate	Moderate	Moderate (7)
Facility I*	Moderate	Moderate	Moderate	Moderate	Moderate (8)
Facility N*	Moderate	Moderate	Moderate	Moderate	Moderate (9)
Facility H*	Moderate	Moderate	Moderate	Moderate	Moderate (10)
Facility S*	Moderate	Moderate	Moderate	Moderate	Moderate (11)
Facility C*	Moderate	Moderate	Low	High	Low (12)
Facility E	Moderate	Moderate	Low	Moderate	Low (13)
Facility L	Moderate	Negligible	Negligible	Negligible	Negligible (14)
Facility Q	Moderate	Negligible	Negligible	Negligible	Negligible (15)

* Burns hazardous waste as fuel.

[a] Future development of land uses around these facilities could increase the exposure potential rankings and, depending on the risk rankings for the other site factors (intrinsic hazard, air contamination potential, and transport potential), could result in higher overall air risk rankings.

[b] The distinction between pH and chemicals is not applicable for the air pathway. The intrinsic hazard ranking for the air pathway is based only on results of totals analyses, which do not include pH (pH is only relevant for liquids).

management practices (13 of the 15 facilities scored moderate for contamination potential). However, to prioritize plants for risk modeling, EPA identified the individual plants posing the greatest potential risk for the air pathway. The three plants ranked as having the greatest risk potential were Facilities A, J, and D. Primary factors that contributed to their ranking included:

- At Facility A, a large exposed surface area of the dust pile (206,000 m^2), limited dust suppression measures (e.g., the pile is not wetted and is only partially compacted), moderate wind speeds, and a relatively moist setting (relatively frequent rainfall and limited evaporation) contributed to an overall moderate ranking for air contamination potential. The close proximity of the CKD pile to the site boundary (30 meters) and moderate distance to the nearest residence (490 meters) suggest a high potential for CKD to be transported to receptors if it is released in the air. Finally, Facility A has a relatively large population within one mile (3,000 people) and much of the land surrounding the plant is used for agriculture (the facility leases some of its own property to nearby farmers), suggesting that both inhalation and food chain exposures could occur if CKD is released to air.

- At Facility J, limited dust suppression practices (e.g., the on-site CKD pile is uncovered, not wetted, and only partially compacted) and moderate rainfall and wind speeds result in a moderate potential for wind erosion from the on-site CKD pile. The proximity to property boundaries (140 meters) and a residence (300 meters) also suggests that CKD could be transported to receptors if released to air. Surrounding agricultural land and pastures provide a pathway for food chain exposure in addition to direct inhalation and incidental ingestion exposures.

- At Facility D, an active dust suppression program (e.g., wetting the pile) moderates the potential releases from a pile with a large exposed surface area (102,000 m^2) in a dry climate. However, the close proximity of the CKD pile to property boundaries (150 meters) and the large nearby population (1,400 people within one mile) suggest that transport of dust and exposures to nearby populations may occur.

Only Facilities C and E were ranked as having a low risk potential for the air pathway. Both of these facilities were ranked low because the potential for transport to exposed individuals for each facility was low. Specifically, the nearest residence at Facility C is 1,100 meters from the pile, and the nearest residence at Facility E is over 1,600 meters from the pile. Therefore, it is unlikely that significant inhalation exposures would occur. However, the air pathway risks do not appear to be negligible because land around each facility is used, in part, for agricultural purposes, creating the potential for human exposures through the ingestion of food contaminated by atmospheric deposition.

Only two facilities were ranked as having a negligible risk potential for the air pathway. These facilities, Facilities L and Q, were assigned negligible risk because all generated CKD is currently recycled.

6.2.2 Risk Modeling of On-site CKD Management

This section presents the methodology and results of the Agency's quantitative fate and transport modeling analysis of on-site CKD management. The first part presents the analytical methodology and the second part presents the results of the on-site risk modeling.

Analytical Methodology

The Agency conducted a quantitative fate and transport modeling analysis to estimate the potential human health and environmental effects associated with current on-site CKD management practices. This modeling analysis extended the results of the risk potential ranking analysis (presented in Section 6.2.1) by quantifying risks at five of the 15 facilities evaluated in that ranking analysis. For each of the three primary direct exposure pathways scored (i.e., air, surface water, and ground water), the two highest ranking facilities in each exposure pathway were selected for the modeling analysis to provide a basis for quantifying the upper end of the risk distribution for the 15 case-study plants. Because some facilities were the first or second highest scoring facility in more than one pathway, this approach resulted in the selection of a total of five facilities for modeling.

As discussed in Section 6.2.1, the risk ranking evaluated a sample of 15 CKD facilities shown to be reasonably representative of the universe of 115 CKD facilities in the U.S. By evaluating risks at two facilities believed to represent the highest risk potential in each of the three direct pathways, EPA selected plants that would be most likely to include those combinations of CKD constituent characteristics, management practices, and exposure settings that might pose the greatest risk to human health from the larger 15-facility sample.

While the methodology focused on evaluating the potential high end of the risk distribution, it also provided an estimate of the central tendency portion of the national risk distribution, because three of the five modeled facilities represented midrange scores in each of the pathways. For example, while Facility G was selected as the highest ranking facility in the ground-water pathway, it represented the eighth ranking facility out of 15 for the surface water pathway. Thus, the modeled surface water risk estimates corresponding to this facility and two others could be used to represent the central portion of the national risk distribution. In this manner, the Agency was able to characterize the central tendency portion of the national risk distribution.

In focusing on the 15 case-study cement plants, it is possible that certain less frequent but potentially high risk CKD management scenarios might not be represented, potentially understating the true high end nationwide risks from CKD disposal. Consequently, the case-study baseline analysis was supplemented with a number of potentially higher risk scenarios to more fully characterize the upper tail of the distribution of national risks. Exhibit 6-10 illustrates these six sensitivity analysis scenarios and their relationship to the baseline central tendency and high end scenarios evaluated in the initial case study analysis.

The baseline on-site CKD management scenarios simulated, as closely as feasible, the actual waste management practices and environmental conditions at the five modeled facilities in order to estimate order-of-magnitude risks at relevant exposure points. Risks were estimated using a standard Agency screening-level model (MMSOILS), a mix of site-specific and regional geographical data, and standard Agency exposure assessment and risk characterization methods. Both individual cancer risks and noncancer human health effects were estimated via air, ground- water, surface water, soils, and the foodchain pathways. Aquatic ecological effects also were estimated for potentially affected surface waters.

The sensitivity analyses of higher risk modeling scenarios were conducted to quantify effects from potentially higher risk waste characteristics, environmental settings, or CKD management practices that have been observed nationally but that were not found at the five baseline facilities. Thus, they are hypothetical yet plausible. Each of these scenarios was based primarily on the baseline case-study facility characteristics; only key risk factors were modified to simulate a potentially higher risk condition. For example, hypothetical upper bound dioxin risks were estimated by simulating dioxin/furan concentrations at the highest levels measured by EPA at each of the five modeled facilities. Thus, this sensitivity analysis scenario combined the basic transport and exposure characteristics of the five original baseline facilities with one selected high risk potential factor (increased dioxin concentrations) to provide an upper sensitivity estimate of the potential contribution of dioxins/furans to CKD risks.

Exhibit 6-10

Graphical Illustration of On-site Risk Modeling Scenarios

The six higher risk scenarios examined, in turn, the following waste characteristics, environmental settings, management practices, or exposure scenarios:

- Disposal of CKD with the highest levels of 2,3,7,8-substituted chlorinated dibenzo-p-dioxins (CDDs) and dibenzo-furans (CDFs) measured by EPA;[9]

- Disposal of CKD with the 95th percentile highest measured metals concentrations based on combined EPA and industry samples from nearly 100 CKD facilities;

- Simulation of a CKD pile located directly adjacent to an agricultural field with uncontrolled erosion of CKD impacting the crops;

- Simulation of a CKD pile located directly adjacent to a surface water body (a lake and a river) with uncontrolled CKD eroding directly to the water;
- Simulation of CKD management in the bottom of a quarry that is covered with water resulting from ground-water seepage; and

- Simulation of potential risks to highly exposed individuals relying on locally-grown produce, beef, and milk, and locally-caught fish for subsistence purposes.

The primary components of the risk modeling methodology used in the baseline on-site scenarios, the higher risk scenarios, and the off-site use scenarios, are summarized below. A more-detailed presentation of the modeling methodology is presented in Chapter 8 of the Risk Assessment Technical Background Document.

Release, Fate, and Transport Modeling Methodology

The CKD risk modeling analysis used the MMSOILS model, a screening-level multimedia contaminant release, fate, and transport model, to estimate ambient concentrations of constituents of concern in ground water, air, surface water, soils, and the foodchain. MMSOILS was developed by EPA's Office of Research and Development to simulate the release of hazardous constituents from a wide variety of waste management scenarios and their subsequent multimedia transport through key environmental pathways.[10] MMSOILS also simulates numerous cross-media transfers of contaminants (e.g., atmospheric deposition to soil and ground water discharge to streams). As a screening-level model, MMSOILS was designed to provide rough order-of-magnitude exposure estimates in relatively simple environmental settings (e.g., granular porous aquifers and relatively flat terrain). Greater uncertainty is associated with the model's application to more complex and heterogeneous environmental settings. See Chapter 8 of the Technical Background Document for a more detailed description of MMSOILS and its use in this risk analysis.

The Agency adopted a screening-level methodology for this analysis both in the selection of MMSOILS and in the nature of the data used in the simulations. The Agency used site-specific, regional, and national level data to characterize the five actual cement kiln facilities. Data for the baseline on-site facilities was obtained primarily from three sources:

- Site-specific data that were collected by the Agency from actual CKD facilities;

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[9] The Agency is currently conducting a scientific reassessment of the cancer potency of CDDs/CDFs. Because this reassessment has not yet been completed, the CDD/CDF risk estimates are subject to revision.

[10] U.S. Environmental Protection Agency, Office of Research and Development, MMSOILS: Multimedia Contaminant Fate, Transport, and Exposure Model, Documentation and User's Manual, September 1992 (updated in April 1993).

- PCA mail survey;[11] and
- Previously collected data on facilities located in similar geographical regions as the case study CKD facilities.[12]

These data represent the best readily available sources for simulating waste characteristics, CKD management practices, environmental settings, and receptor locations at the five baseline on-site facilities. Because many of the environmental setting data characterize the regional setting of a facility rather than its site-specific features, the modeling results represent a rough screening-level indication of contaminant fate and transport in the various environmental media.

The Agency estimated ambient concentrations of CKD constituents of concern in the following exposure pathways/routes:

- Direct inhalation of air;
- Ingestion of contaminated ground water;
- Recreational exposures to contaminated surface water[13]
- Incidental ingestion of contaminated soil; and
- Foodchain ingestion of contaminated vegetables, beef, and milk.

The MMSOILS documentation describes the mathematical approaches used in estimating ambient concentrations in each of these pathways, along with key assumptions and limitations.

There are many sources of analytical uncertainty in any exposure or risk assessment. To better characterize this uncertainty, the Agency's guidance on risk characterization recommends developing both "central tendency" and "high end" risk estimates when conducting risk assessments.[14] The central tendency estimate represents the best estimate of risk, while the high end estimate represents a plausible estimate of the individual risk for those persons at the upper end of the risk distribution. This study adopted the Agency's recommended approach by developing both central tendency and high end risk estimates for CKD facilities.

In addition, EPA guidance recommends accounting for analytical uncertainty wherever possible in risk assessments. In developing this CKD risk assessment methodology, the Agency identified the most significant sources of uncertainty that could result in understating individual risks at the baseline facilities. Because no analytical data were available at the five facilities quantifying environmental concentrations of CKD constituents at exposure points, it was not possible to calibrate the fate and transport modeling methodology with actual site data. Consequently, it was judged that the modeled exposure concentrations represented the most significant source of analytical uncertainty. Accordingly, the Agency generated "best estimate" and "upper bound" constituent concentrations in each exposure pathway at each facility based on best estimate and upper end characterizations of the key environmental transport parameters contributing most to uncertainties in the ambient concentration estimates.

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[11] The 1991 Portland Cement Association mail survey.

[12] These data were collected from EPA Regional offices and states for the Corrective Action Regulatory Impact Analysis currently being conducted by EPA's Office of Solid Waste.

[13] Because none of the five baseline facilities had drinking water supply intakes in any of the rivers downstream of the CKD facilities, exposures from ingestion of surface water as a drinking water source were not estimated in this analysis.

[14] U.S. EPA, 1992. Guidance on Risk Characterization for Risk Managers and Risk Assessors.

Characterization of Exposed Populations

Data were collected on the locations of individuals that could be exposed to ambient concentrations of CKD constituents in each of the exposure pathways analyzed with MMSOILS. The methodology focused on estimating plausible exposure that could reasonably be expected based on actual nearby residential exposure locations. The risk modeling did not estimate risks corresponding to exposures directly on the CKD pile, because the Agency did not identify any residences on abandoned CKD piles; this hypothetical exposure scenario was not addressed further in the study. In addition, because the methodology was based on a risk screening approach, it was not possible to characterize the distribution of risks received by exposed populations surrounding each CKD facility. The approach used in characterizing the exposure points evaluated in the modeling analysis is briefly summarized below.

Direct Inhalation

For estimating individual exposure from direct inhalation of windblown CKD contaminants, USGS quadrangle maps and site visits were used to identify the nearest residence to the CKD pile in any compass direction. For estimating the total exposed population at the site, the total number of residences surrounding the facility were identified out to a distance of 10 kilometers from the CKD pile. (In addition to estimating direct inhalation of airborne contaminants, indirect exposure resulting from wind erosion of CKD particulates were estimated in several of the other exposure pathways described below.)

Surface Water

Sources of drinking water in the vicinity of the five baseline facilities were identified through contacts with the water utilities serving the vicinity of each facility, and it was determined that none of the five areas withdrew surface water for public water supplies downstream from the CKD facilities. Consequently, exposures were not estimated for ingestion of surface water as a source of drinking water. Surface water exposures through recreational swimming were estimated at the point in the nearest surface water body closest to the CKD pile. (Exposures through ingestion of locally-caught fish in the nearest surface water body were also estimated as part of the foodchain analysis.)

Ground Water

The extent of ground-water usage as a local drinking water source was determined through contacts with the water utilities serving communities around each facility. The Agency determined that one of the five facilities had significant private ground-water usage downgradient of the site, while three facilities primarily served by public water supplies were likely to have only limited private well usage; one of the facilities had no ground-water usage within one mile of the facility. Accordingly, individual ground-water exposures were estimated at the nearest residence downgradient of the four facilities with potential ground water usage, while ground-water exposures were not estimated at the fifth facility. Exposure to the potentially affected population at the one site with significant ground-water usage were based on all residences located downgradient of the facility within a distance of two miles; at the other three facilities population risks were not estimated (only individual risks).

Incidental Soil Ingestion

Exposure due to the incidental ingestion of soil were estimated at the residence nearest to each facility that could potentially receive atmospheric deposition and/or erosion from the CKD facility. This location generally represented the closest residence identified for estimating direct inhalation exposures.

Foodchain Pathway

The foodchain pathway analysis generated constituent concentrations in vegetables, beef, milk, and fish at different exposure points in the vicinity of the facility. For vegetables, beef, and milk, foodchain concentrations were estimated at the agricultural field or pasture nearest to the facility. The locations of these fields were identified during the site visits (at one facility), or estimated based on the percentage of agricultural land in the county (at the other four facilities). While these fields and grazing lands were intended to be located on family farms for purposes of the exposure assessment, the actual crops grown and use of these fields was not known (and thus may significantly overstate actual foodchain exposures).[15] Constituent concentrations in fish were estimated at the nearest point in the surface water body closest to the facility. It was not known what edible species of fish were present in these streams or whether the streams are actually used for recreational fishing. Consequently, this scenario may also overstate actual foodchain exposures through fish ingestion.[16]

Exposure Assessment and Risk Characterization

The Agency followed standard guidance, methods, and practice in estimating risks due to exposures at the five baseline facilities.[17,18,19] Best estimate and upper end individual lifetime cancer and noncancer effects were calculated at each exposure point using the best estimate and upper end exposure concentrations from the MMSOILS modeling results. (The Technical Background Document for this human health and environmental risk assessment provides significantly greater detail on the exposure and risk assessment methodologies.)

In this analysis, the Agency estimated individual excess cancer risk for each pathway, which represents the increase above background in the probability of developing cancer over an individual's lifetime in response to contaminant exposures. To estimate excess cancer risks, the Agency multiplied the daily intake of each carcinogen by the cancer slope factor published in EPA's Integrated Risk Information System (IRIS).[20] The highest individual risk for each exposure pathway is the sum of cancer risks calculated for each carcinogenic constituent resulting from exposures at the nearest location to the facility at which an exposure through that pathway could occur (e.g., for the ground-water pathway, the nearest point of ground-water use downgradient of the facility). Total pathway cancer risks represent the constituent-specific risks aggregated across chemicals within each pathway (following Agency guidance, cancer risks were not aggregated across exposure pathways).

The Agency evaluated noncancer effects by determining the ratio of the estimated dose of a particular contaminant to a standard Agency reference dose (RfD). These ratios are

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15 The foodchain exposure pathway analysis was based on the assumption that vegetables grown for human consumption originate in a field located adjacent to the pasture used for grazing the beef and dairy cattle.

[16] The Agency is currently revising its "Methodology for Assessing Health Risks Associated with Indirect Exposure to Combustor Emissions," Interim Final, EPA/600/6-90-003, January 1990, and consequently this foodchain risk methodology is subject to revision.

[17] U.S. EPA, 1989. Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part A). Office of Emergency and Remedial Response. EPA/540/1-89/002.

[18] U.S. EPA, 1991. Human Health Evaluation Manual, Supplemental Guidance: Standard Default Exposure Factors. Office of Emergency and Remedial Response. OSWER Directive: 9285.6-03.

[19] U.S. EPA, 1989. Exposure Factors Handbook. Office of Health and Environmental Assessment. EPA/600/8-89/043.

[20] U.S. Environmental Protection Agency, Integrated Risk Information System Database.

referred to as "hazard quotients." Hazard quotients greater than one for individual chemicals represent an exceedance of an Agency threshold of concern and the possibility of an adverse health effect. Total individual noncancer effects were evaluated by adding the chemical-specific hazard quotients within each pathway, referred to as the "hazard index."

Direct Ingestion Pathways

Exposures through direct inhalation, drinking water ingestion, incidental soil ingestion, and recreational ingestion of surface water were estimated using national average exposure rates, frequencies, and durations reported in standard Agency guidance documents.

Foodchain Pathways

Exposures for the vegetable, beef, and milk foodchain pathways were based on the assumption that the exposed individuals live on a family farm at which they raise a portion of their annual consumption of these food products (or live in a farming community where a significant portion of their food could originate from one local source). Moreover, it was assumed that the home-grown vegetables they consume all originate from the identified agricultural field receiving CKD from the facility, and that their beef and dairy cattle are provided feed from pasture land in the same location. While the extent of consumption of home-grown vegetables, beef, and dairy products will vary significantly on a site-specific basis depending on the types of crops grown, the type of farm, and individual behavior, the considerable variation in exposures on a site-specific basis could not be accounted for in this analysis. In general, it is believed that these exposure estimates may significantly overstate actual consumption patterns. Exposures through ingestion of recreationally caught fish were estimated using behavior patterns for the average individual in the general population as reported in standard Agency guidance.

Sensitive Subpopulations (Childhood Exposures to Lead)

Exposures to lead were calculated for one sensitive subpopulation -- children up through the age of seven years located at the residence nearest to each baseline facility. Because EPA has not published a reference dose for this systemic toxicant, the lead uptake/biokinetic (UBK) model was used to estimate the increased blood lead levels from exposure to lead in CKD.[21] The lead uptake/biokinetic (UBK) model provides a method to predict blood lead levels in target populations (i.e., children ages 0 to 7) exposed to lead in air, diet, drinking water, indoor dust, soil, and paint. Based on user-supplied lead concentrations in each of these potential sources of exposure, the UBK model estimates the relative contributions of each exposure source and the total lead uptake from all sources.

The model presents several different indicators of potential health effect from lead. First, it generates a distribution of blood lead levels for each year of the exposure period (ages 0 to 7) based on the total lead uptake. Second, the UBK model estimates the geometric mean blood level in the exposed population. Finally, the model estimates the percentage of the exposed population that is expected to be at or above a specified blood-lead threshold level (a blood lead level greater than 10 µg/dL was assumed to be the threshold of interest, based on exposure and effect relationships that have been established in infants and children at blood lead concentrations as low as 10 µg/dL).[22]

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[21] U.S. EPA, 1991. "A PC Software Application of the Uptake/Biokinetic Model, Version 0.5," Office of Health and Environmental Assessment (ECAO-CIN-2178A).

[22] A threshold for the noncancer effects of lead is believed to lie within or below the 10 - 15 ug/dL range. Note, however, that this range is regarded as a "level of concern" warranting attention from a medical viewpoint and not a dose level or threshold below which no adverse health effects would be expected to occur. (From U.S. Environmental Protection Agency, "Technical Support Document on Lead," Office of Research and Development, ECAO-CIN-757 (January 1991).

The UBK model accepts inputs for several sources of lead exposure not estimated in this CKD risk analysis: paint ingestion, indoor dust, and drinking water exposures resulting from lead solder pipes. For these sources, which were assumed to be unaffected by the CKD facilities, average background lead concentration levels presented as default values in the UBK model were employed. For those exposure routes used in the UBK model that were estimated by MMSOILS in this analysis, which included dietary intakes (through vegetables, beef and milk, and fish), soil intakes, and atmospheric exposures, the estimated lead concentrations from MMSOILS were added to the national average background values presented in the UBK model. Thus, the blood lead levels estimated in this analysis represent an increment above the national average background childhood blood lead levels estimated by the UBK model resulting from exposures to CKD.

Aquatic Ecological Effects

The Agency estimated potential aquatic ecological effects from CKD releases by relating ambient surface water constituent concentrations to benchmarks for the protection of aquatic life. These benchmarks were either published EPA chronic ambient water quality criteria (AWQC) for the protection of aquatic life, or, where these were not available, lowest observed adverse effect levels (LOAELs) divided by a factor of 5 to account for variations in species sensitivity. Exhibit 6-11 shows the eight constituents for which aquatic ecological benchmarks were available based on AWQC documents and their values. AWQCs are intended to protect aquatic communities against adverse effects on structure or function by protecting 95 percent of the species against adverse population-level effects. These adverse effects are species-dependent and could include reduced reproduction, growth, or survival. Effects of contaminated sediments on benthic communities are not considered.

Exhibit 6-11

Aquatic Ecological Benchmark Levels

Constituents	Aquatic Ecological Benchmark (mg/L)	Source
Antimony	3.2×10^{-1}	LOAEL
Arsenic (III)	1.9×10^{-1}	AWQC
Beryllium	1.1×10^{-3}	LOAEL
Cadmium*	1.1×10^{-3}	AWQC
Chromium (VI)	1.1×10^{-2}	AWQC
Lead*	3.2×10^{-3}	AWQC
Thallium	8.0×10^{-3}	LOAEL
2,3,7,8-TCDD	2.0×10^{-9}	LOAEL

* Assumes a water hardness of 100 mg/L $CaC0_3$

Sensitivity Analysis of Higher Risk Potential Scenarios

The Agency conducted a sensitivity analysis of various factors that could indicate the potential for higher risks from CKD management than exhibited in the baseline risk modeling analysis. A selected number of low probability but potentially higher risk waste characteristics, environmental settings, and exposure assumptions were identified based on site visits, reports from CKD facilities (other than those modeled in the baseline analysis), and in some cases, hypothetical scenarios that could potentially occur but were not specifically observed. In this sensitivity analysis, the Agency examined the extent to which these selected higher risk potential factors, when combined with the baseline central tendency and high end modeling scenarios, could indicate a potential for more significant risks resulting from CKD management.

Two of the sensitivity analysis scenarios examined the sensitivity of the baseline results to changes in waste characteristics:

- The highest measured dioxins scenario estimated the risks associated with the disposal of CKD containing the highest levels of 2,3,7,8-substituted chlorinated dibenzo-p-dioxins (CDDs) and dibenzo-furans (CDFs) measured by EPA during its CKD facility sampling and analysis program. This scenario examined the extent to which the baseline central tendency and high end risk estimates would change if this high CDD/CDF wastestream were present at each of the facilities.

- The 95th percentile inorganic constituent concentrations scenario evaluated the change in risk associated with the disposal of CKD exhibiting the 95th percentile highest constituent concentrations at all five baseline facilities. These 95th percentile concentrations reflect data taken from the EPA sampling and analysis effort and the PCA survey.[23] Because of the low probability that a wastestream containing each of the inorganic CKD constituents at their respective 95th percentile concentration could be found at any single facility, this scenario does not examine the total incremental risk associated with this wastestream characterization, but rather examines only the potential for individual constituents to exceed health effects levels of concern.

Three sensitivity analysis scenarios examined the sensitivity of the baseline risk modeling results to higher risk potential environmental transport scenarios or CKD management practices:

- An EPA damage case study identified a CKD pile located directly adjacent to an agricultural field with uncontrolled erosion of CKD impacting the field. To simulate this scenario, the transport characteristics at two of the facilities modeled in the baseline analysis were modified to simulate exposures associated with the location of an agricultural field or pasture directly next to a CKD pile lacking erosion controls. This scenario focused on the potential effects of this setting on the terrestrial foodchain pathway alone.

- Several EPA damage case studies identified CKD piles that were located directly adjacent to surface water bodies with uncontrolled erosion of CKD entering the water bodies. To simulate this scenario, the environmental transport characteristics at two of the facilities modeled in the baseline analysis were modified to simulate the location of a surface water body (one facility had a river and the other a lake) next to the CKD pile. This sensitivity scenario examined the incremental risks to the recreational swimming and fish ingestion exposure pathways.

- EPA identified several facilities practicing CKD management underwater in a quarry, at which CKD was disposed in a quarry that had been excavated during cement production and that subsequently was filled with water entering the quarry through ground-water seepage. This scenario focused on examining the potential for increased risks through the ground-water transport pathway, although it also examined potential reductions in risk potential through the atmospheric and soil erosion pathways.

[23] Portland Cement Association, 1991. *op. cit.*

The sixth scenario examined in the sensitivity analysis examined the incremental change in foodchain risks associated with an assumption that an individual could rely on vegetables, beef and milk, and fish originating in locations affected by the CKD pile as major components of their diet:

- Potential high exposure due to subsistence food consumption was addressed by estimating exposures of two categories of individuals: subsistence farming and subsistence fishing. The subsistence farming scenario simulates the exposures that could be received by an individual ingesting a high percentage of homegrown produce, beef, and dairy products. For this hypothetical scenario, seventy-five percent of the subsistence farmer's beef, milk, and vegetables are assumed to originate in the CKD-contaminated agricultural field or pasture. The subsistence fishing scenario simulates the exposures to an individual that ingests a high proportion of fish caught locally in a CKD-contaminated surface water body. For this scenario, 75 percent of the fish consumed by the subsistence fisherman is assumed to be caught in the contaminated water body nearest to the facility. These exposure scenarios represent relatively infrequent behavior patterns that have not actually been observed or reported at any of the facilities examined by the Agency.

Results of On-site Risk Modeling

The results from the on-site risk modeling analysis are presented in this section, first for the baseline on-site facilities and then for the sensitivity analysis of higher risk scenarios. Unless otherwise indicated, all cancer risks are reported in terms of excess individual lifetime risk of cancer. Noncancer effects are reported using the previously described hazard index.

Baseline On-Site CKD Management

The cancer and noncancer baseline modeling results are presented below for the direct exposure pathways (i.e., air, ground water, surface water, and soil ingestion) and the foodchain pathways (i.e., vegetables, beef and milk, and fish).

Baseline Direct Exposure Pathway Risks

The Agency calculated a range of high end cancer risks corresponding to both a "best estimate" of facility transport conditions and an "upper bound" characterization of facility transport parameters. This range of high end values presented for each pathway, as shown in Exhibit 6-12, reflects the facility with the highest estimated risks in each respective pathway from among the five modeled facilities. As anticipated in the previous qualitative ranking of risk potential, different facilities were responsible for the highest risk estimated in each of the different pathways.

The central tendency results for the distribution reflect the best estimate of risks from the three facilities with the lowest risk estimates. The central tendency results are presented as a range "less than" the highest value estimated for these three facilities. Thus, the Agency believes that best estimate of the central tendency will generally be less than the reported value (see Exhibit 6-12).

The central tendency baseline modeling results generally indicate a low potential for adverse health effects from current CKD management via the direct exposure pathways. Of the five pathways presented in Exhibit 6-12, the surface water pathway exhibited the highest central tendency risks, estimated at less than an individual cancer risk level of $1x10^{-8}$. The other direct exposure pathway risks were also negligible. The central tendency results for noncancer health effects were all more than four orders of magnitude below the health effects threshold (i.e., the hazard quotients were less than $1x10^{-4}$ in all five direct exposure pathways). These results suggest that most CKD management facilities will not present significant hazards through direct exposure pathways.

The high end risks generally indicated a low threat through the direct exposure pathways, with the exception of the surface water pathway. High end risks resulting from exposures during recreational swimming ranged from $4x10^{-6}$ to $2x10^{-5}$, attributable to arsenic concentrations in the surface water body. The upper bound of the high end risks in the other four pathways never exceeded $1x10^{-6}$, while the best estimate risks at the high end facilities were all less than $1x10^{-9}$. The only noncancer effect within one order of magnitude of the reference dose were for recreational swimming exposures, resulting from the combined systemic effects of arsenic and cadmium. However, the noncancer estimates did not exceed a hazard quotient of 1.0, indicating a low potential threat in the surface water pathway. The high end noncancer estimates in the other four pathways were negligible.

These surface water risks reflect potential exposures in the lake located near Facility J. Because MMSOILS assumes that the lake acts as a sink both for CKD eroding from the pile and subsequently traveling overland to the lake during its operating period, and for windblown CKD that reaches the lake from the pile, it indicates a potential for accumulation of CKD constituents in the lake bed sediments. The potential surface water effects are based on the partitioning of the CKD constituents from the lake bed sediments into the water column. Because of the relative simplicity of the lake simulation component of MMSOILS, the Agency believes these results could overstate the actual high end risks at this facility. Additionally, when fully implemented, the Agency's recently promulgated stormwater runoff control regulations (described in Section 7.2.1 of Chapter 7) could substantially mitigate or eliminate human health risks from surface waters contaminated by stormwater runoff from CKD piles. These regulations would not, however, control delivery of CKD contaminants to surface waters via ground-water or air pathways.

Exhibit 6-12

Baseline On-Site Management Cancer Risks for Direct Exposure Pathways for 15 Case Study Facilities

Exposure Pathway	Excess Individual Lifetime Cancer Risk		
	High End		Central Tendency
	Best Estimate	Upper Bound	
Ground water	$2x10^{-9}$	$6x10^{-8}$	Less than $1x10^{-18}$
Surface water	$4x10^{-6}$	$2x10^{-5}$	Less than $1x10^{-8}$
Direct inhalation	$2x10^{-12}$	$3x10^{-12}$	Less than $1x10^{-14}$
Soil ingestion - adult	$5x10^{-12}$	$1x10^{-7}$	Less than $1x10^{-13}$
Soil ingestion - child	$8x10^{-12}$	$2x10^{-7}$	Less than $1x10^{-12}$

Baseline Foodchain Pathway Risks

As shown below in Exhibit 6-13, while the baseline foodchain pathway results indicated a somewhat higher potential for health effects than in the direct exposure pathways, the central tendency individual cancer risks were still below $1x10^{-6}$, with the beef and milk and fish exposure routes showing negligible central tendency risks at levels less than $1x10^{-8}$. The central tendency noncancer effects were also more than two orders of magnitude below the threshold effects level (i.e., the hazard quotients were all less than $1x10^{-2}$), indicating a negligible likelihood of noncancer impact at those CKD facilities represented by the central tendency estimate.

The high end foodchain estimates varied by pathway, with the ingestion of fish resulting in the highest risks (ranging from $4x10^{-6}$ to $4x10^{-5}$) due to the combined cancer effects of arsenic, beryllium, and potassium-40. High end risks from the ingestion of vegetables ranged from $2x10^{-6}$ to $3x10^{-6}$, resulting from arsenic uptake into the vegetables. The beef and milk exposure pathway results were all less than $1x10^{-6}$ and ranged from $2x10^{-7}$ in the best estimate to $4x10^{-7}$ in the upper bound. The high end noncancer foodchain effects exceeded a hazard quotient of 1.0 in one pathway: ingestion of fish at Facility J resulted in an estimated high end hazard quotient ranging from 4.1 to 16 due to exposures to cadmium. In addition to cadmium, chromium also contributed to this high end noncancer effect with hazard quotients ranging from 0.17 to 0.66. The high end noncancer effects were negligible in the other two foodchain pathways.

Exhibit 6-13

Baseline On-Site Management Cancer Risks for Foodchain Exposure Pathways for 15 Case Study Facilities

Exposure Pathway	Excess Individual Lifetime Cancer Risk		
	High End		Central Tendency
	Best Estimate	Upper Bound	
Vegetable	$2x10^{-6}$	$3x10^{-6}$	Less than $1x10^{-6}$
Beef & Milk	$2x10^{-7}$	$4x10^{-7}$	Less than $1x10^{-8}$
Fish	$4x10^{-6}$	$4x10^{-5}$	Less than $1x10^{-8}$

In estimating the terrestrial foodchain effects (i.e., vegetables, beef and milk), the assumptions concerning the amount of erosion transported from the CKD pile to the agricultural field may result in an overestimate of the impacts in the high end analysis. While the Agency observed effective erosion controls at the five baseline facilities that were believed to effectively restrict the off-site movement of CKD by the erosion pathway, it was believed that these erosion controls could potentially fail in extreme storm events or due to failure of engineered controls. Consequently, the high end analysis adopted a worst case assumption at three of the facilities that these erosion controls would completely fail. Because the high end risks in the terrestrial foodchain pathway were associated with two of these facilities, these high end results may overstate the likely upper bound risks to the foodchain pathway at these facilities.

In total, the baseline modeling analysis simulated the release, fate, and transport of 14 constituents (or in the case of CDDs and CDFs, groups of constituents) that have been detected in CKD and have known cancer or noncancer health effects that could be modeled using current Agency guidance and available data. Exhibit 6-14 shows all of these constituents and the exposure pathways where they exceeded a cancer risk of $1x10^{-6}$ or a hazard quotient of 0.1.

Exhibit 6-14

Constituents Contributing to Adverse Health Effects In On-site CKD Risk Modeling Analysis

Constituents of Concern	Exposure Pathways																Health Effects
	Direct Inhalation		Recreational Swimming		Ground Water Ingestion		Residential Soil Ingestion (Adult)		Residential Soil Ingestion (Child)		Vegetables		Beef & Milk		Fish		
	CT	HE	CT	HE	CT	HE	CT	HE	CT	HE	CT	HE	CT	HE	CT	HE	
Antimony																	Decreased blood cell synthesis
Arsenic				√								√				√	Skin cancer and skin damage
Barium																	Increased blood pressure
Beryllium																√	Gross tumors
Cadmium				√												√	Kidney damage
Chromium																√	Central nervous system effects
Thallium																√	Liver damage
2378 TCDD Equivalents																	Multiple cancers
Potassium 40																√	Cancer
Radium 226/228																	Cancer
Uranium 234																	Cancer
Uranium 238																	Cancer
Thorium 230																	Cancer

Exhibit 6-14 illustrates on a constituent-specific basis that none of the central tendency estimates exceeded a cancer risk of $1x10^{-6}$ or hazard quotient of 0.1. The exhibit shows that the high end risks were the result of exposures to six CKD constituents: arsenic, beryllium, cadmium, chromium, potassium-40, and thallium. Exposures to CDDs/CDFs were not of concern in the baseline risk analysis.

Arsenic, which can cause both systemic and carcinogenic effects, contributed to cancer risks and/or noncancer effects in three high end exposure pathways: exposures during swimming, ingestion of vegetables, and ingestion of recreationally-caught fish. In the swimming and fish ingestion exposure pathways, arsenic exceeded both cancer and noncancer levels, while in the vegetable ingestion pathway, it only indicated a potential threat for its cancer effect (it reached a level just exceeding $1x10^{-6}$). Cadmium resulted in exposures exceeding a noncancer hazard quotient of 0.1 in two high end pathways at one facility: exposures during swimming (ranging from 0.056 to 0.22) and ingestion of fish (ranging from 3.8 to 15). The remaining three constituents contributed to health effects of potential concern only in the high end fish ingestion scenario. Of these constituents, beryllium and potassium-40 indicated potential cancer effects, while thallium exceeded a noncancer hazard quotient of 0.1 for fish ingestion at one facility.

As mentioned previously, full implementation of the Agency's recently promulgated stormwater runoff control regulations could substantially limit human health risks from the ingestion of fish from surface waters contaminated by stormwater runoff from CKD piles. These regulations would not, however, limit the migration of CKD contaminants to surface waters via ground-water or air pathways.

Baseline Estimated Increased Blood Lead Levels

The Agency's methodology for characterizing potential adverse health effects resulting from exposures to lead generated an estimate of the increased blood lead levels above national background levels for children. Using the default assumptions in the UBK model for national average background lead concentrations in the various exposure routes through which children could be exposed to lead, it estimated a national average mean blood lead level of 3.14 µg/dL in children ages one through seven. Thus, in those cases where releases from the CKD facility did not increase exposures to lead above assumed national background levels, the UBK model would estimate a mean blood lead level of 3.14 µg/dL. Where releases from the CKD facility increased exposures to lead, the resulting estimate of the mean blood lead level would represent an increment above this national background estimate.

The estimated mean blood lead levels exceeded the baseline value of 3.14 µg/dL at three of the five baseline facilities, while the two remaining facilities were estimated to result in no increase above national background levels. The estimates exceeded the blood lead effect level of concern of 10 µg/dL at two of these facilities. The highest exceedance took place at Facility J, where the best estimate mean blood lead level was approximately 14 µg/dL, while the upper bound estimate was approximately 48 µg/dL. These increased exposures above background primarily reflect the simulated ingestion of lead in fish caught in the lake at this facility; exposure to lead through the other exposure routes were generally below the national average background levels. Facility A also exceeded the national average background estimates with a best estimate mean blood lead level of about 5 µg/dL and a upper bound estimate of about 13 µg/dL. Finally, the central tendency estimates at Facility F did not exceed background, while the upper bound estimate was approximately 8 µg/dL (which is below the health effect level of concern for blood lead).

Most of the blood lead level estimates indicating an increase above the national background were attributable to ingestion of fish caught in the nearest surface water body to the respective facilities. Because these blood lead estimates are based on the conservative assumption that 20 percent of the child's fish originates in the contaminated surface water body, the Agency believes that they most likely overstate that actual lead exposures associated with most CKD facilities.

Baseline Aquatic Ecological Effects

The examination of aquatic ecological effects focused on eight constituents for which aquatic ecological benchmarks were available (see Exhibit 6-11): antimony, arsenic, beryllium, cadmium, chromium (VI), lead, thallium, and 2,3,7,8-TCDD. In the high end analysis, five of these eight constituents exceeded their aquatic ecological benchmarks (arsenic, beryllium, cadmium, chromium [VI], and lead). The highest values occurred in the nearby lake at Facility J, and ranged from about two times the benchmark value for arsenic to about 300 times the benchmark for cadmium (see Exhibit 6-15 below). Given the relative simplicity of the MMSOILS lake exposure model, it is likely that these values could significantly overstate the actual constituent concentrations in this lake. As Exhibit 6-15 shows, none of the constituents exceeded their respective aquatic ecological health effects benchmarks in the central tendency analysis.

Exhibit 6-15

Results of Central Tendency and High End Ecological Effects Analysis

Modeling Scenario	Ratio of Surface Water Concentration to Ecological Effects Criteria				
	Arsenic	Beryllium	Cadmium	Chromium	Lead
High End	14 - 50	0.5 - 2	80 - 320	37 - 150	14 - 54
Central Tendency	Below AWQC	Below LOAEL	Below AWQC	Below AWQC	Below AWQC

Again, as mentioned previously, full implementation of the Agency's recently promulgated stormwater runoff control regulations could substantially mitigate or eliminate aquatic ecological damages to surface waters attributable to stormwater runoff of CKD contaminants. These regulations would not, however, limit the migration of CKD contaminants to surface waters via ground-water or air pathways.

Sensitivity Analysis of Hypothetical Higher Risk Scenarios

The sensitivity analysis of potentially higher risk scenarios quantified the change in the baseline risks associated with the superimposition of selected high risk potential facility and environmental setting characteristics on the baseline facility characterization. The Agency examined six high risk potential scenarios, which selectively modified the baseline facility estimates as described earlier. The results for each of these six scenarios are presented below in the following order: maximum measured dioxin concentrations; 95th percentile metal concentrations; location directly adjacent to an agricultural field; location directly adjacent to a receiving surface water body; management underwater in a quarry; and risks to possibly highly exposed farmers and fisherman.

Maximum Measured Dioxin Concentrations

This sensitivity analysis examined the change in risks that would occur at the five baseline facilities, based on the hypothetical management of CKD containing the highest measured CDD/CDF concentrations found in EPA's sampling at 11 cement plants (see the Docket for the report on the sampling and analysis results). In order to estimate the sensitivity of the original case-study plant risk estimates to CDD/CDF concentrations, the highest CDD/CDF measured concentrations were substituted into each of the five original facility settings. This scenario is presented to provide an upper tail estimate of potential CDD/CDF risks nationwide. (Because the Agency has only published cancer slope factors for CDD/CDF congeners and has not published reference doses, this sensitivity analysis only examined incremental individual cancer risks and did not address noncancer effects.)

Exhibit 6-16 presents the high end and central tendency results for this sensitivity analysis. In the three primary direct inhalation and ingestion pathways (i.e., ground water, surface, and air), the results were found to be identical to the original baseline risks (presented previously in Exhibit 6-12). The lack of incremental increase in risks above the baseline estimates reflects the fact that CDDs/CDFs did not contribute to these baseline exposure pathway risks due to their lack of mobility in subsurface systems, low solubility in water, and relatively low concentrations in air. The sensitivity analysis did indicate a potential increase in the soil ingestion pathways. The central tendency risks increase by about three orders of magnitude, although they remain negligible (below $1x10^{-9}$). The high risks increased to a similar degree, resulting in risks to adults ranging from $3x10^{-10}$ (best estimate) to $7x10^{-6}$ (upper bound). The risks to children ingesting soil increased to $1x10^{-9}$ in the best estimate to $2x10^{-5}$ in the upper bound.

Exhibit 6-16

Sensitivity Analysis of Maximum CDD/CDF Cancer Risks for Direct Exposure Pathways

Exposure Pathway	**Excess Individual Lifetime Cancer Risk**		
	High End		**Central Tendency**
	Best Estimate	Upper Bound	
Ground water	Identical to Baseline	Identical to Baseline	Identical to Baseline
Surface water	Identical to Baseline	Identical to Baseline	Identical to Baseline
Direct inhalation	Identical to Baseline	Identical to Baseline	Identical to Baseline
Soil ingestion: adult	$3x10^{-10}$	$7x10^{-6}$	Less than $1x10^{-10}$
Soil ingestion: child	$1x10^{-9}$	$2x10^{-5}$	Less than $1x10^{-9}$

The sensitivity analysis indicated a similar increase in risks in the foodchain exposure pathways (Exhibit 6-17). Because the baseline estimates had been higher in the foodchain pathways, the foodchain risks in the sensitivity analysis were correspondingly higher. The risks to the central tendency facilities were about two orders of magnitude greater than in the baseline analysis, and were less than $1x10^{-5}$ in the beef and milk and fish pathways, and less than $1x10^{-4}$ for the ingestion of vegetables. In the high end analysis, the highest risks were found in the fish ingestion pathway and reached an upper bound value of $2x10^{-3}$. Ingestion of vegetables and beef and milk resulted in risks ranging from $2x10^{-4}$ to $6x10^{-4}$.

In both the terrestrial foodchain scenarios and the soil ingestion scenarios, the upper bound risks reflect an assumption concerning the failure of erosion controls at the facilities. As was the case in the baseline analysis, the results presented in this maximum CDD/CDF concentration sensitivity analysis are likely to overstate the risks associated with CKD management.

Exhibit 6-17

Sensitivity Analysis of Maximum CDD/CDF Cancer Risks for Foodchain Exposure Pathways

Exposure Pathway	Excess Individual Lifetime Cancer Risk		
	High End		Central Tendency
	Best Estimate	Upper Bound	
Vegetable	$2x10^{-4}$	$3x10^{-4}$	Less than $1x10^{-4}$
Beef & Milk	$2x10^{-4}$	$6x10^{-4}$	Less than $1x10^{-5}$
Fish	$3x10^{-4}$	$2x10^{-3}$	Less than $1x10^{-5}$

95th Percentile Metals Concentrations

The 95th percentile metals concentration sensitivity analysis examined on a constituent-specific basis the potential for additional CKD constituents to exceed health effects levels of concern. This scenario was evaluated by scaling the baseline risk estimates for each constituent based on the ratio of the metals concentrations in the baseline facility sample and the 95th percentile metals concentrations (see the Docket for the results of EPA's CKD sampling and analysis program). This simplified approach assumes that the risk results in each exposure pathway will be linear with respect to constituent concentration. While this approach may be as accurate as evaluating all of these scenarios directly with MMSOILS, the Agency believes it represents a reasonable estimation of the risks associated with these higher constituent concentrations.

The primary incremental change over the baseline results in this sensitivity analysis was the increased noncancer effects associated with thallium. While it was only within one order of magnitude of the reference dose for the high end fish ingestion in the baseline analysis, it was within one order of magnitude of the reference dose in four additional high end exposure pathways using the 95th percentile concentrations: residential soil ingestion by adults and children, vegetables, and beef and milk. In one of these pathways, vegetable ingestion, thallium was within one order of magnitude of the threshold concentration in the central tendency analysis.

Only two other constituents were within one order of magnitude of the reference dose in a single pathway in addition to those found in the baseline. Antimony had a hazard quotient of 0.12 in the high end surface water pathway. Chromium had a high end hazard quotient of 0.49 in the surface water pathway.

Location Adjacent to an Agricultural Field

This sensitivity scenario focused on the potential for increased risks when an agricultural field or pasture was located directly adjacent to the CKD pile without erosion controls. Accordingly, this scenario only compares the baseline and sensitivity analysis results for the terrestrial foodchain pathways (i.e., ingestion of vegetables and ingestion of beef and milk). This sensitivity analysis only examined two of the five baseline facilities: Facility F (representing the high end estimate) and Facility J (representing the central tendency estimate).

The sensitivity results indicated that risks could increase in the baseline vegetable and beef and milk exposure pathways by between one and two orders of magnitude if the facilities were located directly next to an agricultural field (Exhibit 6-18). Because the scenario assumes no erosion loss during transport between the CKD pile and the field, this high risk scenario would be expected to result in significantly higher risks than at the actual baseline facilities. Both the beef and milk and vegetable exposure routes had similar high end risks, approximately

$4x10^{-5}$. The central tendency risks were somewhat lower, with the vegetable risks about one order of magnitude higher than the beef and milk risks.

Noncancer effects in this sensitivity analysis exceeded the reference dose, unlike in the baseline analysis. The high end hazard quotient for the vegetable pathway was about 6, while the high end hazard quotient for the beef and milk pathway was about 3. The central tendency vegetable pathway hazard quotient was about 5, while the central tendency beef and milk hazard quotient, with a value of about 0.8, did not exceed the reference dose.

Exhibit 6-18

Sensitivity Analysis of Location Adjacent to Agricultural Field for Foodchain Exposure Pathways

Exposure Pathway	Excess Individual Lifetime Cancer Risk		
	High End		Central Tendency
	Best Estimate	Upper Bound	
Vegetable	$3.8x10^{-5}$	$4.2x10^{-5}$	Less than $3x10^{-5}$
Beef & Milk	$4.0x10^{-5}$	$4.3x10^{-5}$	Less than $4x10^{-6}$

Location Adjacent to a Surface Water Body

This sensitivity scenario focused on the potential for increased risks when a surface water body was located directly adjacent to the CKD pile. Because this scenario only affects the exposure pathways associated with the ambient concentrations in surface water, this scenario only examined the recreational swimming and fish ingestion pathways. This sensitivity analysis examined two of the five baseline facilities, both of which are representative of the high end risks: Facility F (representing the high end estimate for a facility bordering a river) and Facility J (representing the high end estimate for a facility bordering a lake). Central tendency risks were not estimated in this sensitivity analysis, which only examined potential changes to the high end estimates.

The high end results for the adjacent surface water scenario showed increased health effects in the recreational swimming and fish ingestion pathways (Exhibit 6-19). In the recreational swimming scenario, the risks were about one order of magnitude higher than the baseline risks, while the noncancer effects reached a maximum hazard quotient of 1.0 in one case. In the fish ingestion scenario, the sensitivity analysis risks were between five and seven times higher than in the baseline analysis. The most significant change in the sensitivity analysis was associated with the increased noncancer effects in the fish ingestion scenario, which reached a maximum hazard quotient of 35 due to uptake of cadmium.

Exhibit 6-19

Sensitivity Analysis of Location Adjacent to Surface Water for Direct and Foodchain Exposure Pathways

Exposure Pathway	Excess Individual Lifetime Cancer Risk		
	High End		Central Tendency
	Best Estimate	Upper Bound	
Recreational Swimming	2.4×10^{-5}	3.3×10^{-5}	Not evaluated
Fish Ingestion	2.3×10^{-5}	3.2×10^{-4}	Not evaluated

Management Underwater in a Quarry

This scenario simulated the increased potential for ground-water contamination resulting from disposal of CKD in a quarry that subsequently fills with water due to ground-water seepage. This sensitivity analysis scenario generated the highest ground-water estimates among all the baseline and hypothetical scenarios. The best estimate ground-water effects, however, remained below a cancer risk of 1×10^{-7}, and more than four orders of magnitude below the noncancer effects level. The high end individual cancer risks reached an upper bound value of about 7×10^{-7}, while the noncancer hazard quotient was within one order of magnitude of a potential effect.

While this sensitivity analysis scenario was not designed to examine risks in the other pathways, the results indicated that this scenario would have the lowest air, surface water, and foodchain effects. Because the CKD is managed underwater and below grade, there is minimal potential for air emissions and erosion run-off, both of which were primary driving forces in the soil and foodchain pathway effects.

Subsistence Level Food Consumption Risks

The Agency evaluated potential risks to individuals highly exposed through two subsistence food consumption scenarios: subsistence farming and subsistence fishing. These hypothetical scenarios evaluated, respectively, potential exposures to an individual that receives 75 percent of his/her vegetables, beef, and milk from sources contaminated by CKD, and an individual that receives 75 percent of his/her diet of fish from a local stream contaminated by CKD. These increased exposure assumptions were superimposed, in turn, on the baseline analysis, the maximum dioxin sensitivity analysis, the adjacent agricultural field scenario (for the subsistence farmer), and in the adjacent surface water body scenario (for subsistence fishing). Thus, this sensitivity analysis examined the combined effects of high foodchain exposures with several individual central tendency and high end risk settings. Consequently, at least in the higher risk scenarios, this analysis tends to compound certain of these highly conservative assumptions related to both the surface water and soil erosion pathways. Accordingly, these results reflect worst case assumptions with a low probability of occurring, and should be evaluated as an indication of the sensitivity of the baseline results to combinations of high risk assumptions.

As would be expected, this scenario produced the highest estimates of risks from the on-site management of CKD. Exhibit 6-20 shows the high end and central tendency cancer risks for subsistence fishing and farming in the baseline analysis, the maximum dioxins analysis, and in the respective adjacent locations sensitivity analyses.

Exhibit 6-20

Sensitivity Analysis of Subsistence Level Food Consumption Risks

Exposure Pathway	Excess Individual Lifetime Cancer Risk		
	High End		Central Tendency
	Best Estimate	Upper Bound	
Subsistence Fishing			
Baseline Analysis	2.0×10^{-4}	1.7×10^{-3}	Less than 6×10^{-7}
Maximum Dioxins	1.3×10^{-2}	6.7×10^{-2}	Not estimated
Adjacent Surface Water	3.5×10^{-3}	1.4×10^{-2}	Not estimated
Subsistence Farming			
Baseline Analysis	1.3×10^{-5}	2.0×10^{-5}	Less than 7×10^{-6}
Maximum Dioxins	4.7×10^{-3}	7.2×10^{-3}	Not estimated
Adjacent Agricultural Field	6.1×10^{-4}	6.7×10^{-4}	Not estimated

The baseline analysis of highly exposed individuals estimated maximum risks at the central tendency facilities of less than 7×10^{-6} for subsistence farming and less than 6×10^{-7} for subsistence fishing. The central tendency noncancer effects were generally within one order of magnitude of the health effects threshold, but did not exceed a hazard quotient of 1. In reality, the Agency does not believe that the average facility represented by the central tendency estimate is likely to have subsistence-level exposures, as this is believed to be a relatively uncommon practice. But these central tendency results suggest that were such individuals located near CKD facilities, most would receive risks ranging below these values.

The high end baseline and sensitivity estimates indicate the greatest risk potential in these two subsistence exposure scenarios. The subsistence fishing scenario results ranged from 2×10^{-4} to 7×10^{-2}, with the highest risks in the upper bound estimate associated with the maximum dioxin concentration analysis. The subsistence farming results were somewhat lower, ranging from 1×10^{-5} to 7×10^{-3}, with the highest risks again occurring in the maximum dioxin concentration scenario. Generally, the high end subsistence level cancer risks were driven by dioxins, arsenic, and in some cases beryllium, while the noncancer effects were driven by arsenic, cadmium, chromium, and thallium.

6.2.3 Summary of Risks from On-site CKD Management

Based on a limited comparison, the sample of cement plants examined in this analysis appears to be generally representative of typical cement plants across the nation in terms of several factors that influence risks. By prioritizing the plants according to risk potential and focusing the modeling on the five facilities that appear to pose the highest risks, EPA attempted to quantify the upper range of the distribution of risks likely to be associated with the 15 case-study plants. In addition, the analysis was designed to quantify the middle range of this risk distribution as characterized by the "central tendency" estimates. The Agency recognizes that the high end results do not necessarily capture the upper bound of the risks that exist across the full universe of 115 active cement plants, as site-specific factors at some plants may contribute to higher risks than estimated for the 15 sample facilities. Therefore, the Agency also conducted a sensitivity analysis of several hypothetical scenarios representing combinations of potentially higher risk scenarios that may exist at other facilities. The findings pertaining to each primary exposure pathway are presented below.

Ground-water Risks

On-site CKD management practices and hydrogeologic conditions create a moderate potential for ground-water contamination at most of the 15 case-study plants. For example, none of the on-site CKD piles examined in the sample are equipped with a synthetic liner or other engineered control to prevent the migration of contaminants to the subsurface, and most sites exist in locations where the net recharge, depth to ground water, subsurface permeability, and other factors could permit shallow ground-water contamination. However, the potential for any such contamination to pose significant risks is diminished greatly by other factors at the majority of sites, including relatively low concentrations of contaminants in CKD leachate, the tendency for several CKD contaminants to sorb to soil and migrate very slowly in ground water, the distance to potential downgradient receptors, and existing ground-water use patterns. Considering all of these factors on a site-specific basis, the central tendency estimate of individual risks for the ground-water pathway were low at each of the facilities modeled (generally, significantly less than an increased individual cancer risk of $1x10^{-10}$ and noncancer effects several orders of magnitude below the relevant effects thresholds). Even in the high end and sensitivity analyses, increased individual risks through ingestion of ground water never exceeded $1x10^{-6}$. Additionally, no cancer cases or noncancer effects were predicted for the populations surrounding the model facilities.

Surface Water Risks to Human Health

The potential for significant human health risks from direct exposures to surface water also appears low at present at most of the case-study plants, due to the lack of surface water usage for drinking purposes downgradient of the facilities. Because the surface water was not used for drinking water purposes, the risk modeling analysis examined exposures resulting from recreational swimming. In the central tendency analysis, the human health effects were below an individual cancer risk of $1x10^{-8}$ and several orders of magnitude below relevant noncancer effect thresholds, based on a recreational swimming scenario assuming exposures from dermal absorption and incidental ingestion of surface waters. In the high end analysis, the risk potential was shown to be greater, with individual risks ranging from $4x10^{-6}$ to $2x10^{-5}$. Important factors contributing to the low central tendency risk estimates include the frequent practice of intercepting and diverting stormwater run-off from CKD piles through on-site ditches prior to discharge to surface water bodies, as well as the distance to and dilution capacity (high flow rate) of receiving creeks and rivers. However, the high end and sensitivity analysis modeling results indicate that higher risks from direct exposure to surface water may exist if stormwater run-off is not adequately controlled and receiving waters have a negligible dilution capacity.

Potential human health risk estimates are higher for ingestion of fish from contaminated waters. While central tendency estimate of effects from consumption of fish caught recreationally were found to be less than $1x10^{-8}$ for cancer and well below the noncancer effect threshold, the high end results reached an increased individual cancer risk of about $4x10^{-5}$ and a noncancer hazard quotient for cadmium at a level about ten times higher than its corresponding threshold.

In cases where CKD facilities are located directly adjacent to a surface water body, both the best estimate recreational swimming and fishing scenarios showed increased cancer risks and noncancer effects roughly similar to the baseline high end estimates. In cases where facilities manage CKD containing the highest concentrations of dioxins measured by EPA, however, the estimated upper bound risks could exceed a cancer risk level of one in one thousand.

In cases where an exposed individual receives 75 percent of their fish from the contaminated surface water body (a subsistence fisherman), the risk analysis predicted significant cancer and noncancer effects. While this may be a relatively rare scenario at actual facilities, the modeling analysis showed this practice to be of relatively significant concern were it to occur.

Aquatic Ecological Risks

The risk modeling analysis evaluated the potential for CKD constituents to exceed aquatic ecological benchmark values in receiving surface waters near the plant. The central tendency results showed no values exceeding chronic ambient water quality criteria (AWQC) for the protection of aquatic life. In the high end analysis, five of the fourteen modeled constituents were shown to have a potential for exceeding ecological levels of concern.

Air Pathway Risks from Windblown Dust

The air pathway is of concern for on-site CKD management because the dust is a fine particulate matter that is readily suspendable, transportable, and respirable in air. Many of the sample facilities add water to CKD prior to disposal to form larger clumps or nodules in an effort to keep the dust down, and some dust suppression is achieved naturally as thin surface crusts form on inactive portions of CKD piles as they are exposed to the elements. Nevertheless, these appear to be temporary and incomplete measures of fugitive dust control at most facilities.

Quantitative modeling of air pathway risks to people living near case-study facilities indicated that wind erosion and mechanical disturbances of on-site CKD piles do not result in significant risks at nearby residences via direct inhalation (e.g., central tendency and high end risks estimates were all less than $1x10^{-11}$ increased individual cancer risk at all five facilities modeled). However, fugitive dust from on-site CKD piles was estimated to be one of two contributors in some cases to higher risk estimates for indirect exposure pathways (which were primarily a result of direct surface run-off from the CKD pile reaching an agricultural field).

Central tendency foodchain cancer risk and noncancer effects for ingestion of vegetables, beef, and milk, were below individual risks levels of $1x10^{-6}$ at all five facilities. In the high end baseline facility scenarios, foodchain risks for ingestion of vegetables reached a maximum of about $3x10^{-6}$. In the sensitivity analysis scenarios, however, these risks reached a maximum of about $2x10^{-4}$ due to uptake of maximum measured CKD dioxin concentrations in vegetables. The estimated risks and hazards for the highly exposed subsistence farmer were significantly higher, reaching a maximum cancer risk exceeding $1x10^{-2}$ in the upper bound sensitivity analysis scenario that simulated the worst case dioxin concentrations. While the frequency of these less common exposure scenarios is likely to be relatively low on a national basis, these risk estimates indicate a potentially significant threat were they to occur.

6.3 EVALUATION OF RISKS FROM OFF-SITE BENEFICIAL USES OF CKD

As discussed in Chapter 8, approximately 943,000 metric tons (1,040,000 tons) of CKD was sold or given away in 1990 for off-site beneficial uses. Most commonly, the dust is used to stabilize hazardous and non-hazardous waste for disposal purposes. About 70 percent of off-site CKD use in 1990 was for this purpose, which is approximately six times more than for any other single use. The next most common off-site use is as a soil amendment, in which CKD mixed with sewage sludge is used as a fertilizer, soil conditioner, or landfill cover. The third most common single use is as a liming agent, in which raw CKD is land-applied directly to agricultural fields. Together, the amount of CKD used as a soil amendment and liming agent accounts for roughly 17 percent (160,000 metric tons) of the total quantity of CKD sold or given away in 1990. A number of other uses also exist, but they are much less common, both in terms of the number of cement plants and quantity of CKD involved. For example, three cement plants sold or gave away about 25,000 metric tons (3 percent of the total) to be used as an additive to concrete and other building materials, and four plants sold or gave away approximately 11,000 metric tons (1 percent of the total) for use in the construction of roads.

This section evaluates the human health and environmental risks associated with these various beneficial uses of CKD. It starts with an overview of the risk assessment approach and methods. The section then evaluates the risks of the following major categories of beneficial uses in turn: hazardous waste stabilization and disposal, sewage sludge stabilization and use, building materials addition, road construction, and agricultural liming. Included in the discussion of sewage treatment and use is an evaluation of the use of stabilized sewage as a landfill cover (one example of soil amendment). Other uses of CKD as a soil amendment (e.g., soil stabilizer) are not addressed because they are expected to pose similar, if not smaller, risks than the direct application of CKD as a liming agent to food crops and pastures. Furthermore, additional uses of CKD, such as an ingredient in livestock feed, a lime-alum coagulant, a mineral filler, an ingredient in lightweight aggregate manufacture, and in glass making, are not evaluated in this chapter because of their limited use. These potential beneficial uses are described in detail in Chapter 8.

6.3.1 Approach and Methods

As a basis for evaluating risks of off-site uses, EPA collected information on how and where the dust is used. This information was obtained primarily through telephone interviews with personnel at a sample of five principal independent companies that receive, process, and/or market CKD at off-site locations. These companies are listed in Exhibit 6-21.

These five companies were selected for three reasons. First, the Agency selected a number of off-site recipients that is roughly proportional to the relative frequency of each category of off-site use: four recipients that mix CKD with either hazardous waste or sewage sludge, and one recipient each for liming agent, road construction, and building materials addition. Second, each company receives and handles a relatively large amount of CKD. With one exception, the sites received more than 900 metric tons (1,000 tons) of CKD from more than one cement manufacturing plant in 1990. Third, the sample of off-site locations represents a diversity of geographical areas.

Exhibit 6-21

Off-site Beneficial Uses Examined in the Risk Assessment

RECEIVING LOCATION	BENEFICIAL USE	QUANTITY OF CKD RECEIVED IN 1990 Metric Tons (Short Tons)
Farmland Ind., Coffeyville, KS	Hazardous Waste Stabilization (petroleum refining sludge)	123,000 (136,000)
VFL Technology, Malverne, PA	Landfill Cover (sewage sludge mixture)	19,000 (20,900)
NewLime, Ravena, NY	Waste Stabilization	53,000 (58,300)
	Road Construction	8,000 (8,800)
	Liming Agent	23,000 (25,300)
National N-Viro Energy Systems, Sioux City, IA	Soil Amendment (sewage sludge mixture)	6,000 (6,600)
U.S. Ash Inc., Roanoke, VA	Materials Addition (concrete admixture)	10,400 (11,440)

Information was developed on productive processes at recipient companies and on basic environmental features at locations where the dust is ultimately used. The Agency then analyzed the factors influencing CKD release, transport, and exposure potential for each category of use, considering the conditions that exist at the sample off-site locations. The purpose of this analysis was to document and describe the major factors that could influence risks from each beneficial use, and to prioritize the uses for further risk analysis through quantitative modeling.

6.3.2 Hazardous Waste Stabilization and Disposal

Farmland Industries is a petroleum refinery that uses CKD to stabilize petroleum sludges prior to land disposal. In 1990, Farmland received approximately 123,000 metric tons (136,000 tons) of CKD, accounting for roughly 17 percent of all the CKD used off-site for waste stabilization that year.

Farmland has used CKD to stabilize a variety of petroleum refining wastewater treatment sludges. The largest quantity of CKD was used as part of a project to close and renovate the refinery's oily sludge ponds in early 1990. These unlined ponds held various wastewaters and sludges, including API Separator Sludge (K051).[24] Investigations conducted at the facility in the early 1980s revealed that ground-water wells downgradient from the oily sludge ponds contained elevated levels of lead, phenols, and hexavalent chromium,[25] as well as a thick layer of oil on top of the water.[26] Therefore, before the land disposal restrictions for K051 became effective in November 1990, Farmland closed the ponds by excavating all the sludge, mixing it with CKD to stabilize it, and disposing of the mixture in a specially created landfill on top of the excavated sludge ponds. The landfill was lined and capped with a local clay.

Since this large closure project in 1990, Farmland has continued to use smaller quantities of CKD to stabilize other listed oil/water/solids separation sludges (i.e., F037 and F038). Farmland presently sends these sludges mixed with CKD off site for disposal in a Subtitle C landfill. Farmland indicates that once the land disposal restrictions for these other hazardous sludges become effective in June 1994, it will begin using a reconfigured wastewater treatment system that will eliminate the need to use CKD as a stabilizing agent.

The potential for CKD to cause or contribute to significant ground-water contamination as it is used by Farmland appears remote. The liner and cap at the landfill containing stabilized wastes from the old oily sludge ponds limit the extent to which water seeps through the wastes and percolates into the subsurface. Monitoring wells have been installed around the landfill and, according to Farmland personnel, have shown no sign of ground-water contamination thus far. Additionally, the off-site landfill where Farmland presently sends its stabilized F037 and F038 is equipped with appropriate controls required under Subtitle C to minimize the risk of ground-water contamination.

The containment provided at the on-site (oily sludge) landfill and off-site Subtitle C landfill also serves to limit the potential for CKD to significantly contaminate surface water. For example, the liner and cover used at the on-site landfill should significantly reduce the extent to which landfill contaminants can migrate to the nearby Verdigris River, either via overland run-off along with stormwater or via ground-water discharge. In addition, Farmland has constructed dikes and berms to control flooding and limit the direct flow of stormwater run-off from the site into the Verdigris River.

Similarly, once mixed with hazardous waste, the dust exists in an oily mixture that is not susceptible to wind erosion. This mixture is ultimately disposed in a covered landfill that effectively prohibits the potential for significant airborne emissions.

Prior to mixing CKD with hazardous waste, Farmland will accumulate a maximum of 9 metric tons (10 short tons) of the dust in an unlined, uncovered pile at the site. Although there is a potential for contaminants to migrate from this CKD pile into the environment, this potential threat appears small compared to that posed by the much larger piles kept on-site at some cement plants. Furthermore, there appears to be nothing unique about the environmental setting at the site that leads EPA to believe that the threat of releases from this small pile at Farmland is any greater than those evaluated for cement plants themselves.

Based on this case-study example, EPA believes that the use of CKD for hazardous waste stabilization does not pose a significant threat to human health or the environment. When mixed with hazardous waste, CKD is subject to full Subtitle C regulation. In fact,

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[24] *Environmental Priorities Initiative, Preliminary Assessment, Farmland Industries Site, Coffeyville, KS*, Ecology and Environment, Inc. prepared for U.S. EPA Hazardous Site Evaluation Division, October 15, 1990.

[25] *Evaluation of the Potential for Migration of Hazardous Waste Constituents from the Disposal Site to Water Supply Sources, Farmland Industries, Coffeyville, Kansas*, Engineering Enterprises, Inc., 1991.

[26] *Inspection of Ground-water Monitoring, Farmland Industries, Coffeyville, Kansas*, Draft Report, Harding Lawson Associates, 1984.

solidification with CKD and other similar agents has been designated as the Best Demonstrated Available Technology for the disposal of several metal-bearing wastes that exhibit a hazardous waste characteristic (55 FR 22520; June 1, 1990). Small quantities of CKD are handled and possibly released into the environment at off-site use locations before the dust is mixed with hazardous waste, but the risks associated with these releases are expected to be minimal. For these reasons, the Agency did not perform quantitative risk modeling for hazardous waste stabilization.

6.3.3 Sewage Sludge Treatment and Use

CKD is commonly used in the treatment of sewage sludge that is then used as landfill cover, fertilizer, or soil conditioner. One treatment approach, the N-Viro process, accounts for a large amount of all of the CKD used in this manner. As discussed in more detail in Chapter 8, the N-Viro process combines CKD with sewage sludge through a patented reaction to produce a "soil-like product."

To evaluate potential risks associated with the use of N-Viro soil, the Agency contacted two vendors that have licensed the process: National N-Viro Energy Systems in Sioux City, IA, and VFL Technology in Malverne, PA. National N-Viro produces and sells N-Viro soil for many uses (e.g., landfill cover, soil fertilizer). VFL, in contrast, operates a production facility at the Middlesex County Municipal Landfill in Middlesex, NJ for the exclusive purpose of producing landfill cover. The VFL plant has an N-Viro soil production capacity of 120 dry tons per day, 7 days per week. In evaluating risk potential, the Agency focused on the use of N-Viro soil as a landfill cover. Use as a soil fertilizer or conditioner is expected to pose similar, if not smaller, risks than the direct application of CKD as a liming agent (evaluated in Section 6.3.6).

The potential for contamination and adverse effects through the ground-water, surface water, and air pathways appears minor when CKD is combined with municipal sludge and used as a landfill cover. At the Middlesex landfill, for example, the landfill itself must meet basic design and operating standards for Subtitle D municipal landfills, including standards designed to limit the seepage of constituents through the landfill base.[27] Ground-water monitoring also is conducted, and according to VFL personnel, no ground-water contamination has been detected since the plant began operation in 1991. The Middlesex landfill also is equipped with berms and dikes to limit stormwater run-on/run-off and subsequent contamination of surface water. The greatest potential for air releases exists during transport of the raw dust to the N-Viro facility. VFL, however, reportedly transports the dust in covered trucks and transfers it directly into the plant via enclosed pipelines. Once CKD is combined with wet sludge, the dust particles are bound to the mixture and are prevented from being suspended in the air. When dried, the potential for airborne releases from the N-Viro product is limited because the fines are bound in large soil-like clumps.

Although there is some potential for the highly alkaline nature of CKD leachate to mobilize certain trace metals that exist in sewage sludge, this threat appears substantially limited by physical processes and existing regulatory and administrative controls. When added to sewage sludge, CKD raises the pH and chemically binds most heavy metals in the sludge. For example, barium, beryllium, cadmium, copper, mercury, nickel, lead, thallium, and zinc tend to be more immobile in ground water under high pH conditions than under low or neutral pH conditions; the reverse tends to be true only for arsenic, hexavalent chromium, antimony,

[27] In October 1991, EPA promulgated expanded criteria in 40 CFR Parts 257 and 258 for solid waste disposal facilities regulated under Subtitle D of RCRA, including the co-disposal of sewage sludge with household wastes in municipal solid waste landfills (56 FR 50978, October 9, 1991). This rule set forth minimum federal criteria for municipal solid waste landfills like the Middlesex County Landfill, including location restrictions, facility design and operating criteria, ground-water monitoring requirements, corrective action requirements, financial assurance requirements, and closure and post-closure care requirements.

molybdenum, and selenium.[28] In addition, EPA recently promulgated technical and permitting regulations that apply to sewage sludge beneficial use and disposal practices (40 CFR Part 503). Thus, fertilizers and soil amendments derived from CKD-sewage sludge mixtures pose minimal risk because these final products are required to be tested to assure they comply with all provisions of 40 CFR 503, which are fully protective of human health and the environment. N-Viro routinely analyzes their sewage sludge to assure compliance with concentration limits established in this "clean sludge" rule for arsenic, cadmium, chromium, copper, lead, molybdenum, mercury, nickel, selenium, and zinc. According to N-Viro personnel, this testing has not detected any exceedances of the clean sludge levels since the facility opened in 1991.

Based on this review, mixing CKD with sewage sludge for use as a municipal landfill cover does not appear to pose a threat to human health or the environment, and the Agency did not undertake more detailed risk analysis through modeling.

6.3.4 Building Materials Addition

To evaluate potential hazards of adding CKD to building materials, EPA contacted U.S. Ash, Inc. in Roanoke, VA, which purchased approximately 43 percent of all of the dust used for this purpose in 1990. U.S. Ash uses CKD to replace cement in general use concrete. Thirty percent of the cement is replaced with CKD and fly ash in equal proportions (i.e., 15 percent of the cementitious product from U.S. Ash is CKD). U.S. Ash does not purchase dust from kilns that burn hazardous waste. The dust is added in dry form to the cement, which is sold to many different customers and used in many different applications.

The possible scenarios for using CKD-containing cement are as numerous and diverse as those that exist for normal cement, and can include its use as water distribution pipelines and structural members of buildings and bridges. Therefore, it is difficult to generalize about potential exposure scenarios associated with this category of use.

One generalization that may be possible, however, is that dust or leachate from CKD-containing cement is unlikely to be significantly different in composition than that from normal cement. This is based partly on the fact that CKD is mixed with cement in only small proportions. Side-by-side leach test data for trace metals published by PCA also suggest that the composition of leachate from cement and CKD are similar.[29] Although these PCA data indicate that the concentrations of relatively volatile metals (mercury, selenium, thallium, cadmium, and lead) may be 13 to 40 times higher in CKD leachate than cement leachate, TCLP tests of both materials yielded metal concentrations that were non-detectable and/or below TC regulatory levels in virtually all cases. Perhaps more relevant results are provided by an independent study[30] that found that metals concentrations in leachate from concrete products were below detectable limits for all metals tested with the exception of chromium, which was measured at 72 ppb, well below the chromium MCL and TC regulatory level. These results indicate that metals, once bound into the cementitious matrix, are unlikely to leach from cement in appreciable quantities and probably do not pose a risk via waterborne pathways.

Similarly, once CKD is locked into concrete, the potential for airborne releases appears low. A potential for air releases does exist during materials handling prior to forming of the concrete, analogous to those observed at the cement production facilities. A potential for fugitive dusting from concrete also exists during use and when the concrete is cut apart or

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[28] Based on soil-water partition coefficients (K_d's) in EPA's Corrective Action chemical database.

[29] Portland Cement Association, 1992. *An Analysis of Selected Trace Metals in Cement and Kiln Dust*. Skokie, IL.

[30] Kriech, Anthony J., *Leachability of Asphalt and Concrete Pavements*, Heritage Research Group,
March 1992.

broken up, either in construction or demolition projects. Such releases, however, would be temporary and the amount of dust emitted to the air is likely to be small compared to that emitted from the large, uncovered CKD piles at cement plants.

For these reasons, EPA believes that the use of CKD as an additive in building materials is not likely to result in significant incremental releases of contaminants to the environment. Additional modeling to quantify risks from this type of use was not conducted.

6.3.5 Road Construction

General evaluation of risk factors suggests that use of CKD in road construction could present a potential threat greater than the other uses discussed above. To evaluate this threat in greater detail, the Agency performed quantitative modeling of a road construction scenario.

Analysis of Risk Factors

NewLime in upstate New York distributed almost 8,200 metric tons (9,000 short tons) of the CKD used in road construction, or approximately 76 percent of all CKD used for this purpose in 1990. Based on telephone interviews with NewLime personnel, CKD can be used in three different ways for road construction: as a road sub-base, mixed with asphalt that is used for the road surface, and in the construction of unpaved roads and parking lots. The potential for releases into the environment varies with these different types of uses.

The potential for releases appears small when the dust is used as a road sub-base. In these situations, the dust is usually mixed with gravel and fly ash. Because CKD and fly ash are pozzolanic,[31] the sub-base sets up to form a solid layer that binds the CKD constituents in place. Leaching and migration from the sub-base also is expected to be limited by little to no direct contact with water, as the sub-base is overlain by relatively impermeable asphalt or concrete. The primary occasions when water may flow under the road and leach CKD contaminants are likely to be associated with freeze/thaw conditions. In addition, there appears to be little potential for windblown dusting, except during the actual application of CKD as a sub-base and the brief period that it is uncovered.

When used as an additive to asphalt, dust in the asphalt could be submerged during rainfall. In principle, CKD constituents could leach from the asphalt mixture and migrate to ground water or flow overland to surface waters. However, a study by the Heritage Research Group[32] shows that metals normally present in asphalt do not tend to leach in appreciable concentrations during TCLP tests. For almost every metal tested, concentrations in asphalt leachate were below detectable limits. The only exception was chromium, which was detected in asphalt leachate at a level of 0.10 ppm, 50 times below its TC regulatory level. It is not known how CKD affects the leachability of asphalt, if at all. However, the generally low concentrations of chemicals observed in CKD leach tests and the relatively small proportion (five percent or less) of CKD that is mixed with asphalt suggest that asphalt mixed with CKD would produce leachates very similar to asphalt by itself. The potential for airborne releases when CKD is used in asphalt also appears low because the dust is locked into a matrix through a pozzolanic (hardening) reaction. The presence of small proportions of CKD is not expected to significantly affect the quantity and quality of particulates that are suspended from the asphalt during road use.

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[31] That is, finely divided siliceous or siliceous and aluminous material that reacts chemically with slaked lime at ordinary temperature and in the presence of moisture to form a strong, slow-hardening cement.

[32] Kriech, Anthony J., *Evaluation of Hot Mix Asphalt for Leachability*, Heritage Research Group,
October 1992.

A greater potential for CKD contaminants to migrate into the environment appears to exist when the dust is mixed with clayey soils to form unpaved roads or parking lots. In these cases, the dust may be applied in an indiscriminate manner that is not designed to optimize a pozzolanic reaction. Moreover, the dust is not covered by a hardened road surface like asphalt or concrete, and engineered controls are not used to prevent CKD contaminants exposed to the elements from leaching into the subsurface or migrating to any nearby fields or surface waters along with storm water run-off. CKD also could be blown into the air by the wind, and vehicular traffic both during and after construction could periodically and temporarily suspend particulate matter into the air. The primary factors that would influence the amount of CKD suspended in the air include the particle size of the material on the road surface, traffic volumes, the speeds and other characteristics of vehicles (e.g., number of wheels and weights), and rainfall patterns.

Based on this evaluation, there does not appear to be a significant human health or environmental risk associated with the use of CKD as either a road sub-base or an additive to asphalt. However, since there appears to be a greater potential for releases of CKD contaminants and subsequent exposures when the dust is used in the construction of unpaved roads or parking lots, these risks were studied in greater detail through quantitative modeling.

Risk Modeling Results for Unpaved Traffic Surfaces

The Agency employed the same basic modeling methodology for quantifying the risks from off-site use of CKD for unpaved roads and parking lots as was used in the on-site analysis (Section 6.2.2). The primary difference relates to the design of the road paving scenario. Because such uses may take place in virtually any location in the U.S., this risk scenario is largely hypothetical and was developed using best professional judgment. Thus, the results from this analysis should be considered rough indications of the kinds of risks that might correspond to this CKD management approach.

The Agency simulated direct addition of CKD to the other materials (clayey soils and aggregate) used in the construction of an hypothetical off-site parking lot. Because MMSOILS requires a square source term, it cannot effectively simulate releases from a long thin source such as would be required to simulate a road. Accordingly, the analysis was limited to the use of CKD in unpaved parking lots. The release modeling for unpaved parking lots considered three of the four pathways evaluated in the on-site modeling: ground water, air, and surface water. Only one exposure pathway in the foodchain pathway was evaluated: ingestion of fish in a nearby stream.

Based on this modeling, the estimated risks associated with use of CKD as a surface for unpaved parking lots were generally quite low. None of the pathways examined were found to have cancer risks exceeding the 10^{-6} risk range or noncancer effects exceeding the threshold dose.

The highest risks were in the foodchain pathway (for ingestion of fish in the nearby stream receiving run-off from the parking lot). The only foodchain pathway effect evaluated for unpaved parking lots corresponds to the ingestion of fish caught recreationally in the nearby stream. The increased individual cancer risk associated with recreational fishing was estimated to be about 1×10^{-7}, due to exposures to 2,3,7,8-TCDD. Noncancer effects were about two orders of magnitude below the effects threshold, with thallium representing the highest intake to reference dose ratio.

The maximum ground-water risks from the unpaved parking lot were estimated at 5.3×10^{-9}, which were driven by potassium-40. The noncancer effect was nearly seven orders of magnitude below the effect threshold. The low ground-water effects resulted from the low permeability of the unpaved surface (resulting in minimal leachate generation) combined with the relatively low concentrations of the CKD constituents in the leachate generated by the parking lot material.

The increased individual cancer risks through exposure to air emissions were estimated to be 1.4×10^{-11} to the individual living closest to the parking lot. Noncancer effects were negligible and could not be quantified. These low air risks reflect the small size of the unpaved parking lot, which is unlikely to serve as a large enough source to result in elevated ambient concentrations of CKD constituents in the air.

The estimated maximum risk resulting from dermal absorption and incidental ingestion of water while swimming was 2.4×10^{-9}, and was due primarily to arsenic. Noncancer effects were estimated to be about five orders of magnitude below the health effects threshold.

6.3.6 Agricultural Liming

Because of the potential for bioaccumulation and the direct ingestion of contaminated food products, CKD used as a liming agent appears, on first evaluation, to pose more of a potential risk than any other CKD use. To further explore this risk potential, EPA performed quantitative modeling of an agricultural liming scenario.

Analysis of Risk Factors

Like agricultural lime, CKD is alkaline and contains a number of essential plant nutrients. According to the 1991 PCA Survey and the RCRA §3007 responses, approximately 53,000 metric tons (58,000 tons) of dust were sold or given away in 1990 for liming from five cement plants (one plant each in New York, Pennsylvania, and Kansas, and two in Idaho). To evaluate this application, the Agency contacted the NewLime Company in upstate New York. NewLime distributes dust to over 1,600 farmers and accounted for approximately 46 percent of the total dust used for liming in 1990.

NewLime is the exclusive CKD agent for Blue Circle Cement in Ravena, NY. The dust is transported from Blue Circle to storage silos at NewLime via enclosed trucks. CKD in storage at NewLime is subsequently transported from the silos to specific points of application via bulk tanker trucks. The dust is not modified in any way prior to application. The typical point of application is a 41-hectare (100-acre) farm that grows alfalfa, corn, and soybeans for livestock feed. Alfalfa and corn account for about 90 percent of the crop output. Approximately half of the CKD from NewLime is applied in New York.

Liming may occur during any season of the year with the majority occurring in the fall. Once the dust arrives at a farm, it is placed in spreader boxes of spreader trucks. These boxes commonly hold up to 11 metric tons of CKD and measure approximately 10 meters (33 feet) in width. Two and a half centimeter (1-inch) diameter holes on the bottom of the spreader boxes are spaced every 10 centimeters, which enables CKD to be applied evenly to the fields. CKD is applied in four steps. The farmer first disks the soil and harrows the ground; CKD is then spread; the soil is disked again; and the farmer plows a final time. CKD is usually tilled to a depth of 15 to 20 centimeters. Typically, 4.5 metric tons of CKD are spread per hectare with CKD application occurring once every three to five years. This is the same as the application rate for regular lime.

A paucity of available data on the composition of agricultural lime prevents a complete comparison of CKD and lime in terms of trace contaminant concentrations. However, a preliminary analysis suggests that, compared to CKD, agricultural lime can contain higher totals concentrations of some constituents (such as barium), about equal concentrations of some constituents (such as chromium), and lower concentrations of other constituents (including lead, nickel, silver, vanadium, and copper).[33] Agricultural lime would not be expected to contain dioxins because it is simply crushed limestone, and not, like CKD, manufactured in a combustion process along with chlorine precursors that might yield dioxins.

The potential for ground-water contamination from liming is a function of the amount of CKD applied, dust leachability, and the particular environmental conditions that exist at a farm (e.g., rainfall and recharge rates, soil chemistry and permeability, and depth to ground water).

[33] Boynton, Robert S., *Chemistry and Technology of Lime and Limestone*, Second Edition, John Wiley & Sons, Inc., New York, Chichester, Brisbane, and Toronto.

As noted above, the dust is applied infrequently in small amounts, just like regular lime. No data are available, however, to compare contaminant concentrations in leachate from regular lime to those measured in CKD leachate extracts. The environmental conditions where the CKD is applied may vary widely because CKD liming takes place not only throughout upstate New York, but also in a few other locations in the United States. At some sites, these conditions may be conducive to ground-water contamination, such as when net recharge rates are high, soils are permeable, and ground water is shallow. Furthermore, because ground water in rural areas around farms is often used for drinking and other purposes, any ground-water contamination associated with the use of CKD as a liming agent may have the potential to result in human exposures.

Similarly, there is a potential for this use of CKD to result in surface water contamination. The only measures that may exist to prevent CKD contaminants from migrating into surface waters are likely to be occasional irrigation ditches and agricultural management techniques designed to preserve topsoil, such as terracing. Vegetation may slow run-off to surface waters during the growing season, but when CKD is applied initially, little or no vegetation exists. Even during the growing season, much bare soil is exposed to the elements in fields with row crops. Factors such as CKD application rates, CKD properties (e.g., chemical composition and leachability), annual rainfall, the slope of the land, the nature of on-site soils, the extent of crop cover, and the distance to surface waters will all contribute to the potential for surface water contamination.

In general, when properly handled, the potential for release to air when CKD is used as a liming agent appears smaller than the potential for release to ground water and surface water. In the specific example of NewLime, the dust is covered and contained during all phases of storage and transport prior to the time it is applied to a field. In particular, CKD is transported in enclosed trucks to the NewLime storage facility, where it is then stored in enclosed silos. The dust is then transported from NewLime to individual farms in enclosed tanker trucks where it is placed in enclosed spreader boxes. The dust is dropped only centimeters above the ground and quickly tilled into the soil; it is not broadcast in the air and then allowed to settle onto the ground. In the Agency's telephone interview, NewLime personnel indicated that little dust becomes airborne even on windy days.

The greatest potential for contaminant exposures resulting from the use of CKD as a liming agent is through the foodchain. Crops cultivated in fields limed with CKD by NewLime are used as feed for livestock. CKD constituents, therefore, may be ingested directly by animals and concentrated in food products (milk, meat) that are ingested by humans.

Risk Modeling Results for Liming

The Agency conducted a quantitative analysis to estimate the potential magnitude of risks resulting from the agricultural use of CKD. As in the unpaved road analysis, the modeling methodology for the agricultural applications of CKD was based largely on the approach used in analyzing on-site risks. The primary differences concern the focus on the two foodchain exposure pathways relevant to agricultural applications: vegetables, and beef and milk. Because the CKD is assumed to be tilled directly into the soil, this analysis did not quantify potential impacts to surface water, air, or fish ingestion, as it is assumed that these results would be significantly lower than risks from the ingestion of agricultural products. Another difference from the on-site modeling analysis included the simulation of three basic risk scenarios: best estimate, high end, and upper bound. The best estimate analysis assumed the best estimate CKD application rate and CKD concentrations representing CDD/CDF values from a facility that has been documented as selling CKD for use as a liming agent, and 50th percentile values for the metals and radionuclides from the Agency's database on CKD concentrations. The high end analysis used a high end CKD application rate and CKD concentrations corresponding to the highest risk potential wastestream from the five baseline facilities. Finally, the upper bound value used the high end application rate, and CKD concentrations from the facility with the highest measured CDD/CDF concentrations from the Agency's sampling and analysis program.

The Agency simulated direct incorporation of CKD on a hypothetical agricultural field assumed to grow corn or alfalfa for use as cattle feed. The field used in the simulation represented a typical 41-hectare (100-acre) field. The analysis employed an assumed CKD loading rate of 4.5 metric tons per hectare (2 tons per acre) every four years in the best estimate and the same loading every two years in the high end and upper bound analyses.

The best estimate results for the liming agent analysis showed the following for the three foodchain exposure scenarios examined. The highest best estimate risks were in the subsistence farmer scenario, reaching a maximum cancer risk of $7x10^{-6}$ for arsenic, with the next highest risk resulting from beryllium exposures (at $4.7x10^{-7}$). Ingestion of vegetables (non-subsistence) resulted in a risk of $8.4x10^{-7}$ for arsenic, while the ingestion of beef and milk resulted in a risk of $1.1x10^{-7}$.

The high end results (more frequent every two year application of CKD with higher constituent concentrations) exceeded those in the best estimate by one to two orders of magnitude. The subsistence farming scenario had the highest total cancer risks of $2.5x10^{-5}$, resulting equally from exposures to arsenic and 2,3,7,8-TCDD equivalents. The risks for ingestion of vegetables were $1.7x10^{-6}$ (due to arsenic), while the risks from beef and milk ingestion were $1x10^{-6}$ due to 2,3,7,8-TCDD equivalents and arsenic.

The upper bound scenario simulated the tilling of CKD with EPA's highest measured CDD/CDF concentrations in the field. This scenario produced the highest risk estimates, with a maximum risk of $2.1x10^{-4}$ for the subsistence farming scenario (due primarily to 2,3,7,8-TCDD equivalents), a cancer risk of $1.7x10^{-5}$ for beef and milk ingestion (dominated by 2,3,7,8-TCDD), and a cancer risk of $1.1x10^{-5}$ for the ingestion of vegetables (resulting from 2,3,7,8-TCDD, arsenic, and beryllium).

None of the noncarcinogens exceeded the effects threshold in the liming agent analysis, although several constituents resulted in hazards within one order of magnitude of the threshold (i.e., a hazard ratio between 0.1 and 1.0): antimony (high end subsistence farming only), cadmium (all subsistence farming scenarios and high end vegetables), and thallium (subsistence farming and beef and milk ingestion).

6.3.7 Summary of Risks from Off-site Beneficial Uses

By far, the most common off-site use of CKD is for waste stabilization, both for hazardous and non-hazardous waste prior to disposal and non-hazardous waste (municipal sewage sludge) prior to beneficial use. Based on an evaluation of the conditions that exist at sample off-site locations where CKD is used, EPA believes that these uses do not pose a significant threat to human health or the environment. Hazardous waste stabilization presents a low risk because CKD mixed with hazardous waste is subject to full Subtitle C regulation, including requirements for disposal in lined units to prevent ground-water contamination, appropriate run-on and run-off controls to prevent surface water contamination, and capping of landfills upon closure to prevent air releases. Releases to various media are further minimized because CKD is generally mixed with sludges to form a stabilized solid that is less susceptible to dispersion (e.g., via wind erosion) than CKD by itself. For non-hazardous waste stabilization, the risks are also expected to be small because at least half of the CKD used in this manner in 1990 was used in the N-Viro process, which combines CKD with sewage sludge. Similar to Subtitle C regulations for hazardous wastes, sewage sludge disposal is controlled by recently promulgated permitting regulations (40 CFR Part 503). These regulations set forth concentration limits for metals in sludge before disposal. Compliance monitoring of stabilized sludge at a sample off-site use location indicates that no exceedances of clean sludge levels have occurred.

Three other off-site uses — road sub-base, additive to asphalt, and materials addition — also do not pose significant risks. When used for these purposes, CKD is mixed with other materials, such as asphalt or cement, to form a solid matrix. In this form, it is unlikely that the CKD will contaminate environmental media because: (1) the CKD makes up only a small fraction of the total solid matrix (e.g., less than five percent in the case of asphalt mixtures); and

(2) the solid matrix is generally not susceptible to significant releases to ground water, surface water, or air.

Preliminary evaluation identified two types of uses that could have a greater potential to pose risk to human health and the environment: agricultural liming and construction of unpaved roads and parking lots. The primary risk conclusions for these off-site uses are as follows:

- For agricultural liming, releases to ground water and surface water are possible due to leaching and surface run-off. Air releases are not expected to be significant because the dust is covered and contained at all times during transport and delivery, dropped only centimeters from the ground during application, and is quickly tilled below the surface. EPA's modeling predicted potential risks via the foodchain pathway for this practice for ingestion of vegetables from the field, beef and milk raised on feed from the field, and most significantly, for a farmer subsisting on both vegetables, beef, and milk raised from the field. The best estimate cancer risks reached a maximum of $7x10^{-6}$, while the maximum high end risks were $2.5x10^{-5}$. In the bounding analysis, the subsistence farming scenario showed the greatest risk potential with a risk estimate of $2.1x10^{-4}$.

- For use in unpaved roads and parking lots, releases to ground water, surface water, and air could occur because the CKD is not fixed in a solid matrix, but is slightly compacted, exposed to the elements, and disturbed by vehicular traffic. However, the Agency's modeling predicted very low risks (less than $5x10^{-9}$) for the ground-water, air, and surface water pathways, and only $1x10^{-7}$ for the worst-case scenario of fish ingestion in the adjacent surface water body. Noncancer risks were found to be below the combined effects threshold for all pathways evaluated.